FCG 185

British Columbia Assessment of Science

Provincial Report 1991

MINISTRY OF EDUCATION AND

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SCIENCE IN BRITISH COLUMBIA

The 1991 British Columbia Science Assessment
Provincial Report

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P. James Gaskell
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&
Marvin Wideen
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This report was a joint product of all members of each of the Contract Teams.
Their names are listed in the Appendix and their assistance and expertise were essential to this report.

1991 Science Assessment
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Ministry Responsible for Multiculturalism
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THE CONTRACT TEAM

For the 1991 Science Assessment, the Contract Team was divided into four different groups, representing four different components, who worked together to conduct the overall assessment.

THE CLASSICAL COMPONENT

The team for this component was responsible for the written teacher questionnaires, student background information, student attitudes, multiple-choice questions, and the written open-ended questions of student knowledge.

Classical Component Contract Team

David Bateson (Chair)	University of British Columbia
John Anderson	University of Victoria
Susan Brigden	University of British Columbia
Elaine Day	Simon Fraser University
Burt Deeter	36 Surrey
Catherine Eberlé	39 Vancouver
Bruce Gurney	44 North Vancouver
Mike Marshall	Educational Measurement Research Group
Vivian McConnell	39 Vancouver, retired

THE PERFORMANCE COMPONENT

This team examined students' abilities to manipulate science equipment and materials, perform simple hands-on tasks and solve problems using equipment, and investigate more complex science questions using materials and equipment.

Performance Component Contract Team

Gaalen Erickson (Chair)	University of British Columbia
Anthony Bartley	University of British Columbia
Lorna Blake	University of British Columbia
Robert Carlisle	University of British Columbia
Karen Rice-Meyer	University of British Columbia
Ruth Stavy	University of Tel Aviv

THE SOCIOSCIENTIFIC ISSUES COMPONENT

This team investigated how students understand and respond to science-related social issues presented in either video or print formats.

Socioscientific Issues Component Contract Team

P. James Gaskell (Chair)	University of British Columbia
Reginald Fleming	University of Saskatchewn
Renée Fountain	University of British Columbia
Alfred Ojelel	University of British Columbia

THE CONTEXT OF SCIENCE COMPONENT

This team visited and observed numerous science classrooms and talked to students, teachers, and administrators about science teaching and learning. This process provided both a context for the other parts of the assessment and, most importantly, a picture of what science teaching and learning is like in the classrooms of this province.

Context of Science Education Component Contract Team

Marvin Wideen (Chair)	Simon Fraser University
Elaine Day	Simon Fraser University
Barbara Graham	Simon Fraser University
Allan McKinnon	Simon Fraser University
Barbara Moon	Simon Fraser University
Charlie Naylor	Simon Fraser University
Tom O'Shea	Simon Fraser University
Ivy Pye	Simon Fraser University
Reginald Wild	University of British Columbia

ACKNOWLEDGEMENTS

After close to three years of work, the members of the Contract Team wish to thank all those individuals who worked so hard to bring this assessment to fruition.

Appendix A contains the names of all the members of each of the various committees, panels, and teams who had official duties in the assessment. The Contract Team wishes to particularly acknowledge the members of the Assessment Review Committee. They devoted many hours of weekend, evening, and holiday time, in addition to what was normally expected, to ensure that everything connected with the assessment was of the highest possible quality. Others integrally involved with this assessment include:

The district and school administrators and secretaries who ensured that the assessment was conducted as smoothly as possible.

Officials with the Ministry of Education, particularly Jim Gaskill, Amy Brydon, Bill Toth, Vaughan Lewis, and Ross Norrington, who devoted much of their time and effort to the assessment. Marie Ann Maruca, who provided assistance during the final preparation of this manuscript. In addition, many clerks, secretaries, and other employees who spent countless hours working on the details of the logistics of the assessment.

Associates with the Educational Measurement Research Group, particularly Mike Marshall, Bob Taylor, Reid Able, Bob MacDonald, and Peter Cheung, who were always willing and able to meet the demands of the Contract Team.

The members of the Contract Teams for the other components of the assessment, particularly the chairpeople, Gaalen Erickson, Jim Gaskell, and Marvin Wideen, who worked so hard to link and make sense of vastly different approaches, methodologies, and data types.

Numerous graduate students at all three of the universities involved, the University of British Columbia, the University of Victoria, and Simon Fraser University who provided assistance and it is hoped benefitted from the experience.

Finally, the greatest thanks goes to the thousands of teachers, and students in British Columbia who participated in the assessment during the piloting, the interviews, and the actual administration. Without their cooperation, the assessment could never have been conducted!

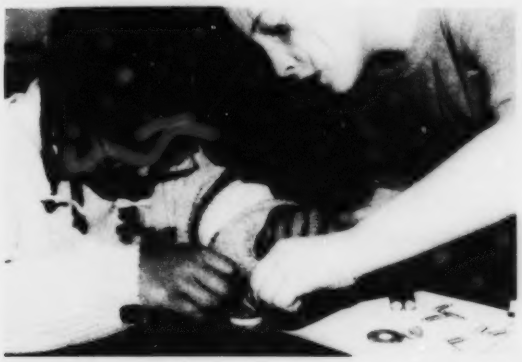
Photographs in Chapters One and Two, "The Classical Component" and "The Performance Assessment Component," were taken by Robert Carlisle.

Note: The photographs on the opposite page and in Chapters One and Two illustrate the student tasks. On the next page and in Chapter Two, the dialogue is a composite of comments made by many students and by several researchers. It is not attributable to any particular student or researcher, nor to the students pictured on these pages.

INVESTIGATING

Elizabeth and Paula arrive ahead of schedule, walk to the desk on which all the materials are arranged, and sit down at my invitation. They sit, unsmiling, upright, scanning the desk top, the materials, and occasionally look at me:

"Which of the three magnets in front of you is strongest? While you answer the question, I will sit here and make some notes about what you do. I hope I do not disturb you. Please work together and talk to each other."



Silence.... Both pick up a magnet and turn it over slowly in their hands, while looking at the materials, sullen-faced and unmoving. Suddenly:

Elizabeth: *"I know what to do. Let's see how many balls they will pick up."*

Paula nods and picks up the tube of iron filings and puts the magnet close to the glass.

Paula: *"Hey! Look! It stands up."*
Elizabeth: *"It holds 4 balls, the red one holds 4."*

The pair repeat the testing of the red and black magnets using steel balls, paper clips, nails, small washers and steel cubes. They are puzzled as sometimes one magnet holds more objects and sometimes the other holds more.

They review their work and decide that black wins over red, 4 to 2. Black holds more washers, balls, paper clips, and steel cubes. This review is carried out from memory of the previous tests. There are no written records.

Paula: *"Black's stronger. Yes, definitely it's stronger."*
Elizabeth: *"Yes, and silver is no good, and red is second."*

Paula: *"Can we take the graphite (iron filings) out of the bottle?"*

"Sure," I say, and off they go, enjoying the playful experience of a particulate material that behaves like a liquid. Eventually we tidy up and the children leave. As they reach the door Elizabeth asks,

"Was the black magnet really stronger?" and Paula chimes in, *"What is the right answer anyway?"*

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INTRODUCTION

THE 1991 BRITISH COLUMBIA SCIENCE ASSESSMENT REPORT

The 1991 British Columbia Assessment of Science is the fourth in-depth examination of school science that has been conducted in British Columbia; the others were conducted in 1978, 1982, and 1986. This document is a condensed report of the total assessment. More detailed information about the various parts of the assessment is available in separate reports from the Ministry of Education and Ministry Responsible for Multiculturalism and Human Rights. These larger, technical reports contain the data and evidence on which statements and conclusions made in this report are based.

This report begins with a section on the values of science education and of the science assessment in general. The structure of this assessment is then explained, followed in turn, by the results of each of the components of the assessment. Within each section, suggestions for change and improvement are made. Results relating to themes found in each of the four components are collated as central issues in a summary section. The report concludes with a major recommendation stemming from the assessment.

WHAT DO WE VALUE IN SCIENCE EDUCATION?

When an assessment of student learning is undertaken in an educational system, the report is laden with value. Our values as educators and citizens must come to bear in the very things we look at in developing an assessment. In order to understand the relationship of science teaching practice and outcomes to what we value in the name of science teaching, we must ask the question, "What counts as a science education?" We begin to speak of broad goals for science teaching that are set out in educational policy. This is not an easy task, for not only are there subtle shifts in the way science education has been justified historically, but these intentions may also vary considerably at any given time among the various "stake-holders" in our educational system.

At the outset of this summary report, then, it is worth a brief pause to consider the curriculum goals and objectives surrounding the teaching of science. Essentially, we are raising the fundamental question "Why teach science?"

At first glance the answer seems rather obvious; we teach science so that children will learn that science is good in its own right. However, when we look a little deeper into the political, economic, and social contexts of science education, we begin to see many other reasons for teaching science.

Traditionally, one of the reasons science was taught was so young people would develop an understanding of the physical world, particularly in terms of developing explanations for everyday occurrences and the technologies of the day. For example, electricity was taught to understand how the electric bell or telegraph worked; heat and temperature were taught in terms of learning how the furnace in a house operates, or how a steam engine works, and so on. The intent of the school science curriculum was to educate students about "everyday applications", and this approach can be clearly seen in the science textbooks of days gone by.

Science education changed significantly when it became a vehicle for achieving other ends. There came a time when we wondered if we were producing enough scientists and technologists in western society, and whether we would be able to compete in the world market during a time of rapid technological change. In the early sixties, for example, there was a concern that America would lose the "space race" to the Soviet Union, and Canadians became worried about political and economic stability. The justification for science education both in Canada and the U.S.A. began to shift toward learning about science as a field of inquiry for the purpose of producing more scientists for the work force. In the hopes of developing an appreciation and understanding of the "structure of science," rather than its applications, students were taught about scientific theories and processes. Practical applications of science such as the telegraph and steam engine disappeared from the curriculum in favour of pure science.

Recently, there has been an increased desire to have students learn science so they will better understand societal issues related to science (also termed socioscientific issues). Heat and temperature might be taught under this curriculum intention in a manner that would allow students to make judgements concerning what kind of insulating materials might be used in a particular building, the sort of economic and environmental considerations surrounding the use of these materials, and whether they would present any health problems to the occupants of the building. In this case, science is being taught to develop students' understandings of the relationships among "science, technology, and society."

Today, science is taught for many reasons. We hope that, through the study of science, students will develop an understanding of their everyday world, that they will develop some appreciation for the nature and history of science as an area of human inquiry, and that they will become informed citizens, capable of making sound decisions with respect to science and societal issues. We hope that, through the study of science, our young people will come to know what "active inquiry" is all about, so they will learn about their own potential as rational people, and learn to trust their ability to think problems through for themselves.

It is important to have an appreciation for what we value in science teaching when it comes to interpreting the results of the learning assessment of science. One component of this assessment deals with students' responses to science-related social issues (The Socioscientific Component). Another component deals with students' abilities in laboratory investigations and their skills at designing scientific investigations, generating and testing hypotheses, controlling variables that influence experimental outcomes, etc. (The Performance Component). Still another component is concerned with students' knowledge of scientific facts and principles, the more familiar arena of assessment for most of us who may not be involved directly with the educational system today (The Classical Component). A final component of this assessment examines science teaching and learning in action in a variety of classroom settings (The Context of Science Component).

CURRENT GOALS IN THE SCIENCE CURRICULA

An examination of recent curricula and general education documents in British Columbia reveals that the principal intention of science education is to foster "scientific literacy" through:

- developing a positive attitude toward science;
- expressing scientific attitudes;
- developing science skills and processes that allow for exploration and investigation of the natural world;
- understanding and communicating principles and concepts that provide a scientific perspective on the world;
- appreciating cultural and historical contributions to science; and
- understanding how science, technology, and society interact and influence one another, creating socioscientific issues.

Such a broad statement of the purposes of science education in British Columbia is the first step in determining what is important in a science education. With this understanding it is then possible to read and appreciate this report on the 1991 British Columbia Science Assessment in the proper light.

Goal A

The Science Program should provide opportunities for students to develop positive attitudes toward science.

Goal B

The Science Program should provide opportunities for students to develop the skills and processes of science.

Goal C

The Science Program should increase students' scientific knowledge.

Goal D

The Science Program should provide opportunities for students to develop creative, critical and formal (abstract) thinking abilities.

Specific objectives within these goals vary depending upon grade level. Interested readers should consult the following curricula guides:
CG0094 *Elementary Science Grades 1-7 (1988),*
CG0153 *Junior Secondary Science Curriculum Guide and Resource Book (revised 1985).*

PURPOSES OF ASSESSMENTS IN GENERAL

This assessment is one of many assessments that have been conducted in British Columbia since 1977. At the present time, Ministry documents state that, in general, the program of regular assessments is designed to:

- inform professionals and the public of some of the strengths and weaknesses of the public school system;
- assist the Ministry, school districts, and schools in decisions related to the development, review, modification, revision, and implementation of existing curricula and supporting instructional resource materials;
- assist the Ministry in decisions concerning allocation of resources;
- identify areas of need and provide directions for change in both pre-service and in-service teacher education;
- provide directions for educational research;
- monitor student learning over time; and
- provide the province, school districts, and schools with information that can be used to maintain strengths and overcome identified weaknesses.

However, as initiatives pertaining to the *Year 2000* are implemented, assessments will necessarily undergo an evolution in their structure and their emphasis on each of the stated purposes.

PERSONNEL OF THE ASSESSMENT

The Ministry of Education provides the resources necessary for any assessment and also provides assistance throughout the process. The assessments are conducted by an independent Contract Team of qualified educators and evaluators, assisted by a large number of teachers, trustees, parents, and members of the general public, each of whom plays a specific role in the overall assessment process.

The Appendix of this report provides a description of the roles and responsibilities of each of the teams, committees, and panels who played a direct part in the assessment, followed by a list of the personnel involved in each group.

THE ASSESSMENT PROCESS

The Ministry of Education determines the timing and general questions for each assessment and selects the Contract Team following a bidding process. Systematic stages of conducting assessments have been developed over the years and follow a set pattern common to all British Columbia assessments.

TECHNICAL REPORTS

Full and detailed accounts of the components are contained in the individual technical reports of the four components of the assessment. These reports and all instruments, materials, information and data (recoded to ensure anonymity) are available from Learning Resources Branch.

FCG 185	*British Columbia Assessment of Science Provincial Report 1991.*
FCG 186	*British Columbia Assessment of Science 1991 Technical Report I: Classical Component.*
FCG 187	*British Columbia Assessment of Science 1991 Technical Report II: Student Performance Components.*
FCG 188	*British Columbia Assessment of Science 1991 Technical Report III: Socioscientific Issues Component.*
FCG 189	*British Columbia Assessment of Science 1991 Technical Report IV: Context for Science Component.*

STRUCTURE OF THE ASSESSMENT

The 1991 Science Assessment, which shared the above overall purposes, followed a very different pattern from previous science assessments. Previous science assessments had used only written student and teacher questionnaires and had based judgements about student achievement only on student answers to a group of multiple-choice questions. The 1991 Science Assessment used a variety of techniques and methods to examine the current science program. The student achievement instruments, while using all the techniques of previous assessments, also required students to provide written responses to open-ended questions, problems, and instructions. In addition, teams of observers visited many schools to interview teachers and students, and to observe science classes in action, students doing science activities, and pairs of students investigating science problems. As in previous assessments, this assessment focused on Grades 4, 7, and 10, which are chosen to represent students at the end of the primary, intermediate, and junior secondary programs. This assessment also expanded the sample to include students enrolled in all grades from 3 to 10. This variety of methods has provided a much richer picture of science education in British Columbia than has ever been available in the past.

It should be noted that recent Ministry policy has renamed the four primary years Kindergarten to Grade 3, and now Grade 3 is called "P4" or "Last-year Primary". However, for clarity, this report will consistently use the terminology "Grade 3".

WHO TOOK PART IN THE ASSESSMENT?

A stratified random sample of schools in British Columbia including all types of schools, large or small, from all areas of the province was drawn for the assessment. The results are provincially representative for the Classical, Open-Ended, and Socio-scientific components. These are shown in the shaded area of the following diagram. The results of the Performance Tasks and Classroom Context components are indicative of students' work and the science teaching in classrooms around the province. For these two components the sample was not large enough to be statistically representative. Therefore, results cannot be generalized across all districts or to any one particular district.

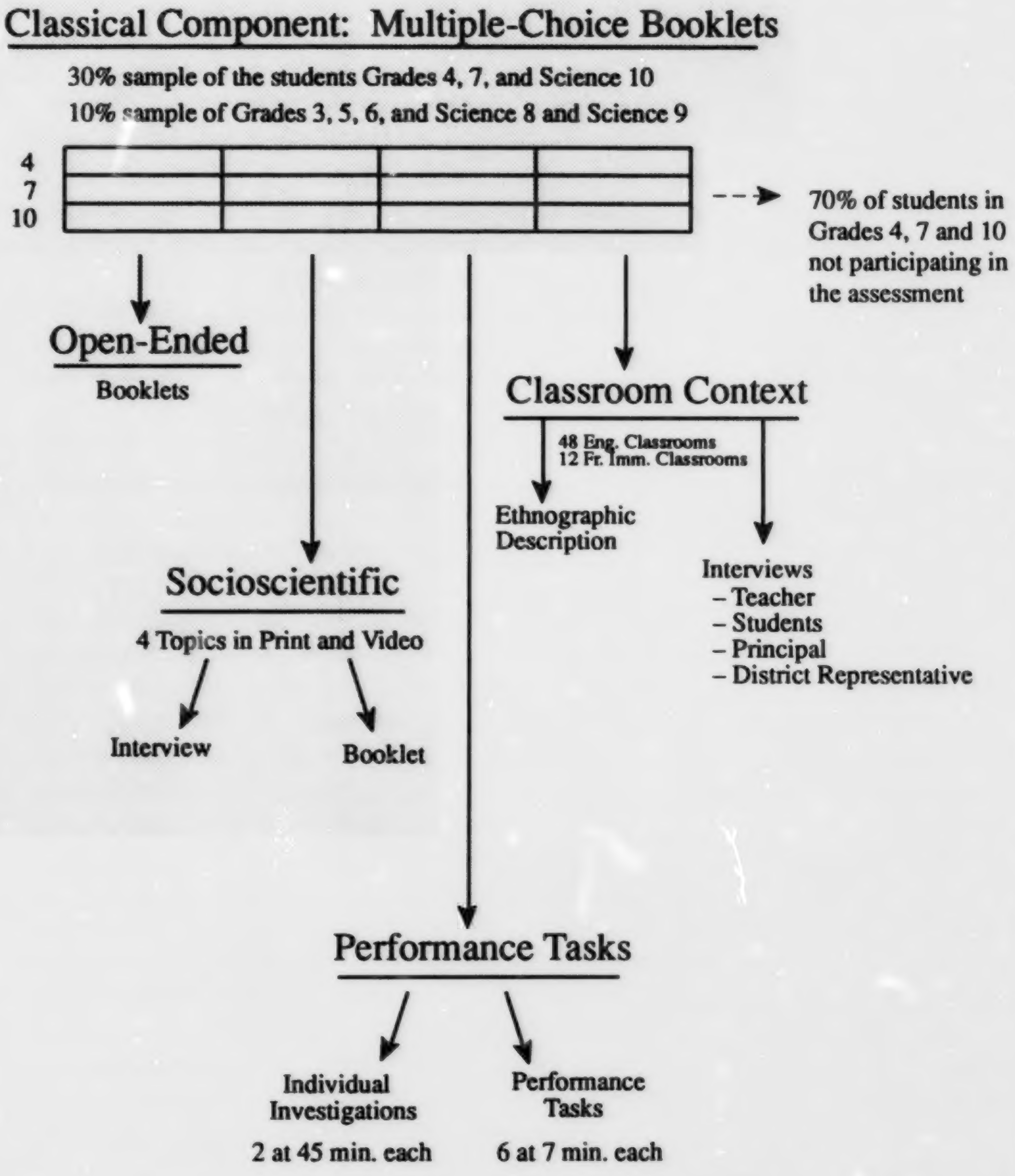
Provincial Assessment results for students registered in French Immersion and Programme-cadre de français programs were analyzed and reported separately in the Technical Report of the Classical Component. All teachers who taught science at Grades 4, 7, and 10 were asked to complete a teacher questionnaire. More detailed information on sampling is available in the technical reports.

Participants in the 1991 B.C. Science Assessment

Grade	# of Schools	# of Teachers	# of Students
Grade 3	152	——	3988
Grade 4*	342	1550	10645
Grade 5	121	——	3374
Grade 6	113	——	3067
Grade 7*	314	1228	10434
Grade 8	62	——	3492
Grade 9	42	——	3179
Grade 10*	87	612	7329
TOTAL		**3390**	**45508**

* Focus Grade

Overview of Science Assessment Components


Classical Component: Multiple-Choice Booklets
4
7
10
Open-Ended
Booklets
Socioscientific
4 Topics in Print and Video
Interview
Booklet
Classroom Context
48 Eng. Classrooms
12 Fr. Imm. Classrooms
Ethnographic Description
Interviews
– Teacher
– Students
– Principal
– District Representative
Performance Tasks
Individual Investigations
2 at 45 min. each
Performance Tasks
6 at 7 min. each

30% sample of the students Grades 4, 7, and Science 10

10% sample of Grades 3, 5, 6, and Science 8 and Science 9

70% of students in Grades 4, 7 and 10 not participating in the assessment

THE CLASSICAL COMPONENT

CHAPTER ONE

The Classical Team first surveyed the literature on science education and assessment and carefully examined curriculum documents and resource materials available for science in the schools. On the basis of these analyses, tables of specifications, or "blueprints" for the various assessment instruments were developed. All materials were subjected to a series of careful and detailed review procedures. They were then pilot tested, field tested, and put through a series of editing procedures resulting in a final selection of the actual items to be used in the assessment. The administration of instruments and the site visits for collection of data were conducted in the spring of 1991. Following scoring and coding of the data, Provincial Interpretation Panels examined the results and provided guidance to the Contract Team in making recommendations and completing the final reports to the Ministry.

Within the classical component, all sampled students answered background information questions, attitude scales, and multiple-choice questions. One-tenth of the students sampled also provided written answers to open-ended type questions. All teachers of Grades 4, 7, and 10 Science completed teacher questionnaires.

STUDENT BACKGROUNDS AND ACTIVITIES

The assessment asked several questions about students' backgrounds, and in-school and out-of-school activities related to science. Some consistent trends were noticed.

For the in-school activities, students who reported that they either "never" or "always" took part in a particular activity consistently scored lower than the other students. This was true for all grade levels. Although these findings may seem, at first glance, to be contradictory, they suggest that lower student performance is associated with a concentration on a limited number of activities or methodologies within a classroom, while ignoring other activities and methodologies; students who reported engagement in a wide variety of activities and methods, each used to a moderate extent, scored highest. Since other research also confirms that students tend to achieve best when presented with a wide variety of thoughtfully-presented activities and methods, teachers should be made aware of the need to vary the activities and teaching methods they use in the classroom. A large percentage of students reported that they rarely or never used library materials, used computers, or went on field trips for science. It would seem that these resources should play an important part in teaching science to today's students and should be made widely available. Teachers should be encouraged to make use of such materials and activities, as available.

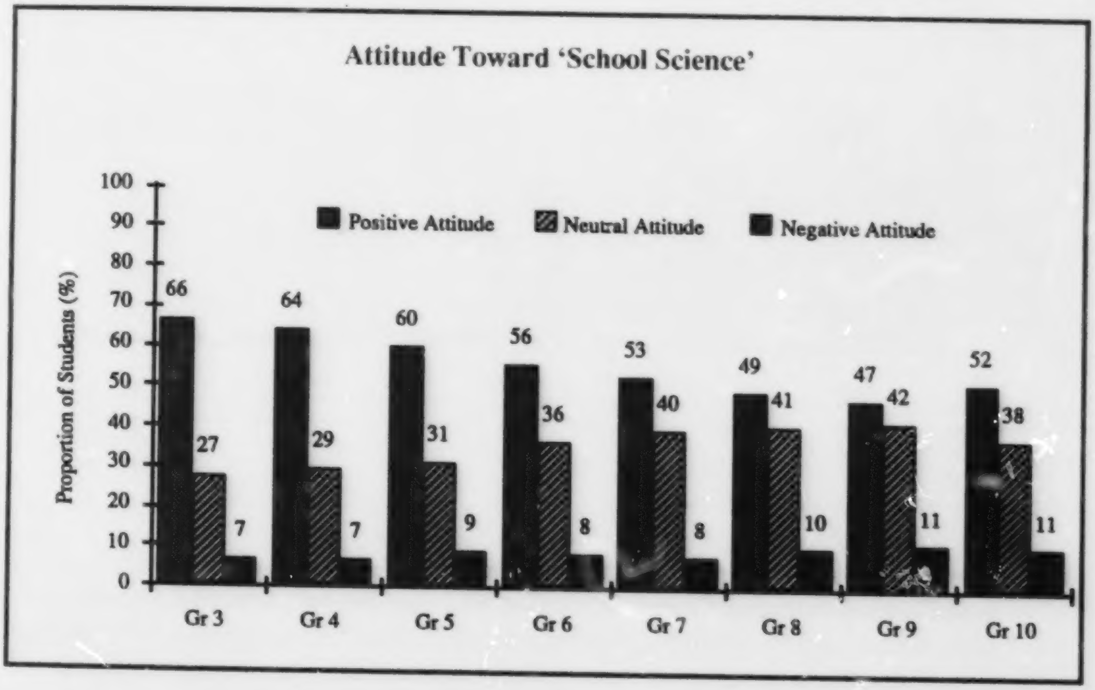
A large proportion of students, even at Grade 4, have had considerable experience in out-of-school science-related activities. Students who have experience with science-related activities such as visiting aquariums, planetariums, museums, Science World, nature centres; watching science-based television programs; reading science-related materials; and participating in science fairs show higher performance on the achievement surveys. One should not conclude that taking students to an aquarium will necessarily raise their test scores; it may be that students who are better at science want to take part, and therefore do take part more in these types of activities. It is, however, logical that students learn science during these activities and that more students should be encouraged to take part in them, where available.

STUDENT ATTITUDES

According to Goal A of the British Columbia Elementary and Jr. Secondary science curriculum guides, students in B. C. are expected to develop positive attitudes toward science. In this assessment, through both Likert-type scales and semantic differential measures, attitudes toward "School Science", "Science in Society", "Careers in Science", and several selected "Environmental Issues" were examined .

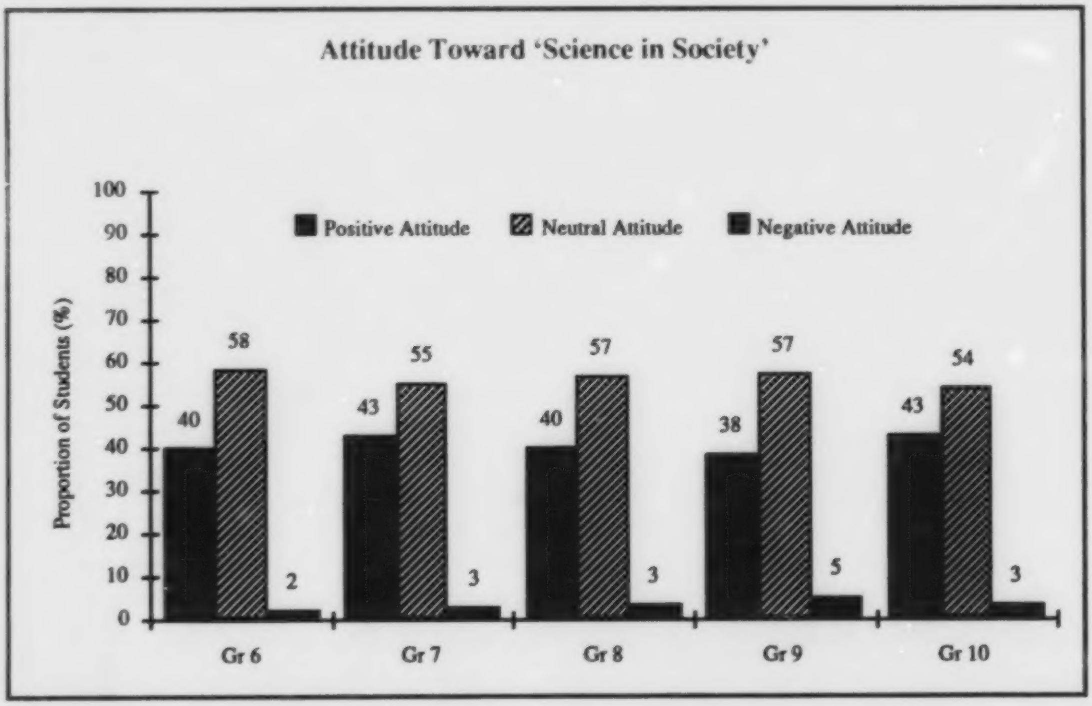
SCHOOL SCIENCE (ALL GRADES)

The majority of students in B.C., as shown in the graph below, has a positive attitude toward school science. However, as the students get older, the proportion of students who feel positive toward studying school science decreases but, at the same time, attitudes do not become negative but rather more neutral regarding school science. It is heartening to note that the general trend of a decline in attitude toward school science as the students progress through the grades appears to halt and even reverse itself at Grade 10.



SCIENCE IN SOCIETY (GRADES 6-10)

As shown in the graph below, while a large proportion of students appear to feel positive about the overall value of science to society, and very few feel negative, the majority of students appear to hold a more neutral attitude. Student responses were more positive for those individual items that were concerned with the "importance of science to society in general" than their scores on the total scale might indicate. For example, 76% of Grade 7 students and 80% of Grade 10 students agreed or strongly agreed with the statement that "science is important to our lives".

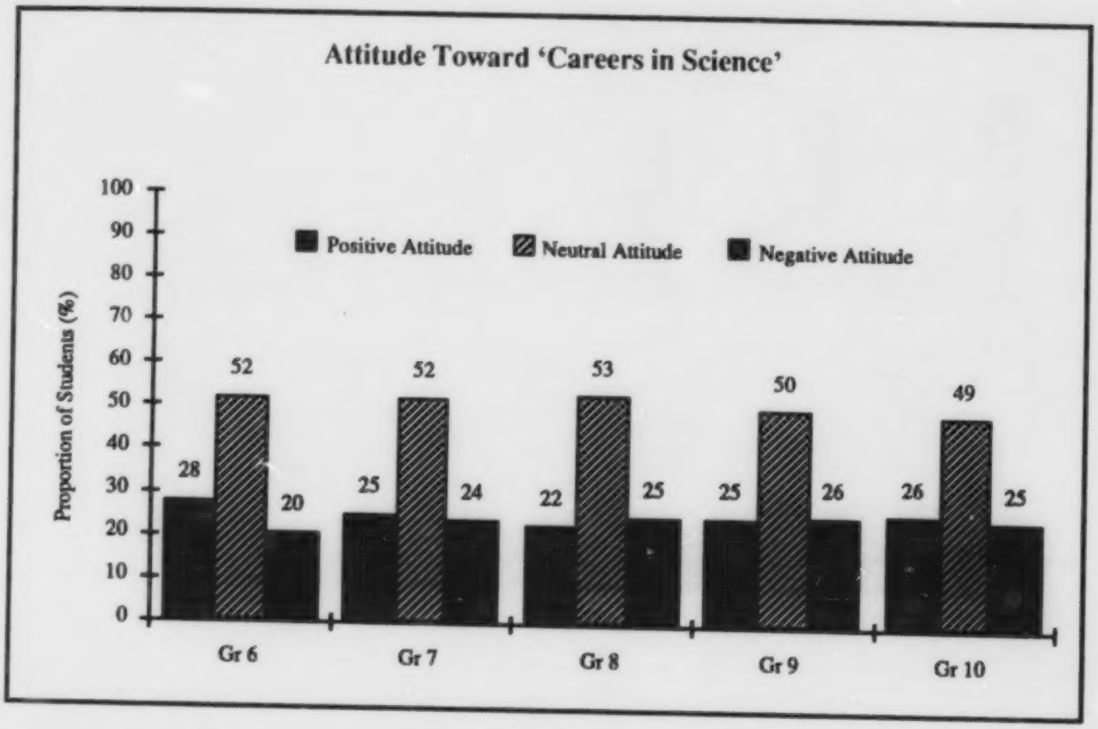


CAREERS IN SCIENCE (GRADES 6-10)

The graph below shows that about one-quarter of B.C. students at each grade feel positive about pursuing a career in science, while the largest proportion of students feels neutral, and therefore possibly open minded about a science career. The proportion of students within each attitude category is nearly the same at all grade levels, which is somewhat surprising given that the older students are getting to the age where they will have to make decisions about their educational programs and their careers.

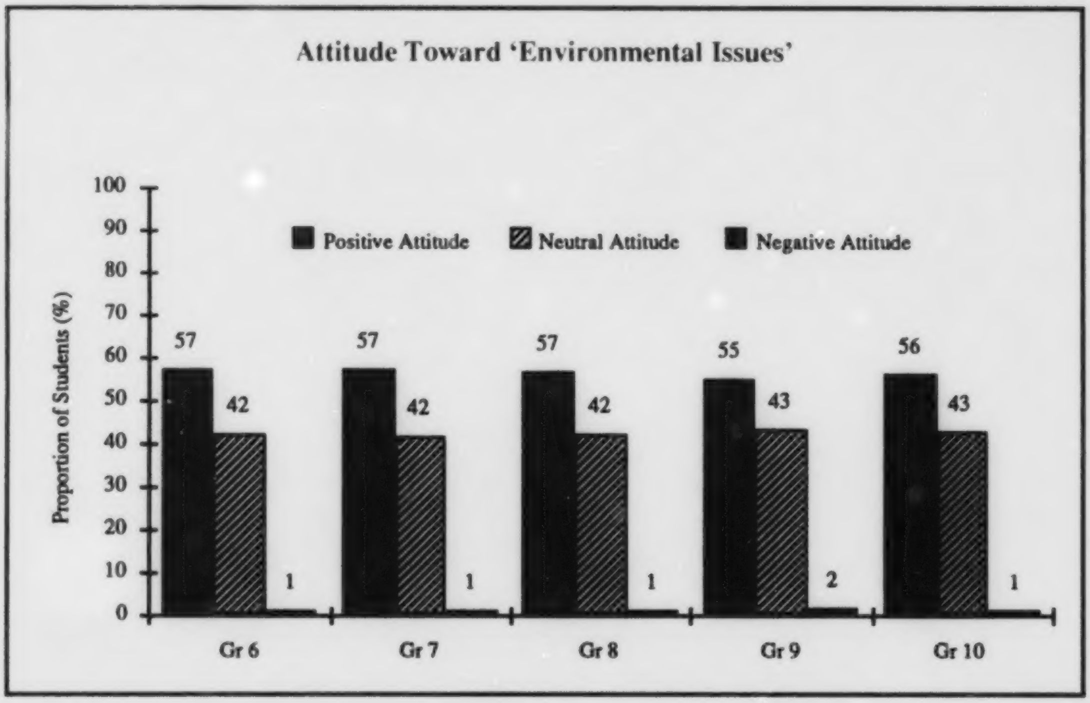
It was expected that the number of students falling within the neutral category would decrease as students get older and become more certain about the type of career they would like to pursue. One has to wonder if students are receiving enough information about careers in science that could help them to make their career decisions. There are many complex reasons for career choices, but perhaps students still have a limited and restricted view of a person engaged in a career in science, rather than as an engineer, medical technician, forester, or any other of the myriad of science-related occupations available to both men and women. Many people have predicted that the future economic and social well-being of Canada will be dependent, to a major extent, on Science and Technology. Concern has been expressed regarding the proportion of students having positive attitudes toward a career in science.

Society in general, and schools in particular, must work to instill knowledge about, and positive attitudes toward a career in science and science-related fields.



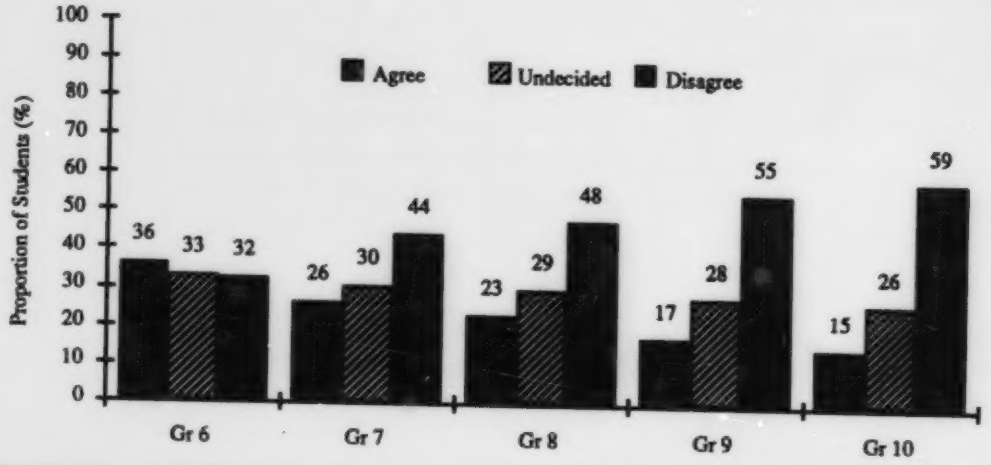
Environmental Issues (Grades 6-10)

In general, students at all grade levels have positive attitudes toward environmental issues. The following graph displays the percentages of students who displayed overall positive, neutral, and negative attitudes. As can be seen, fewer than 2% of the students at any grade had what might be termed as an "unfriendly" environmental attitude.



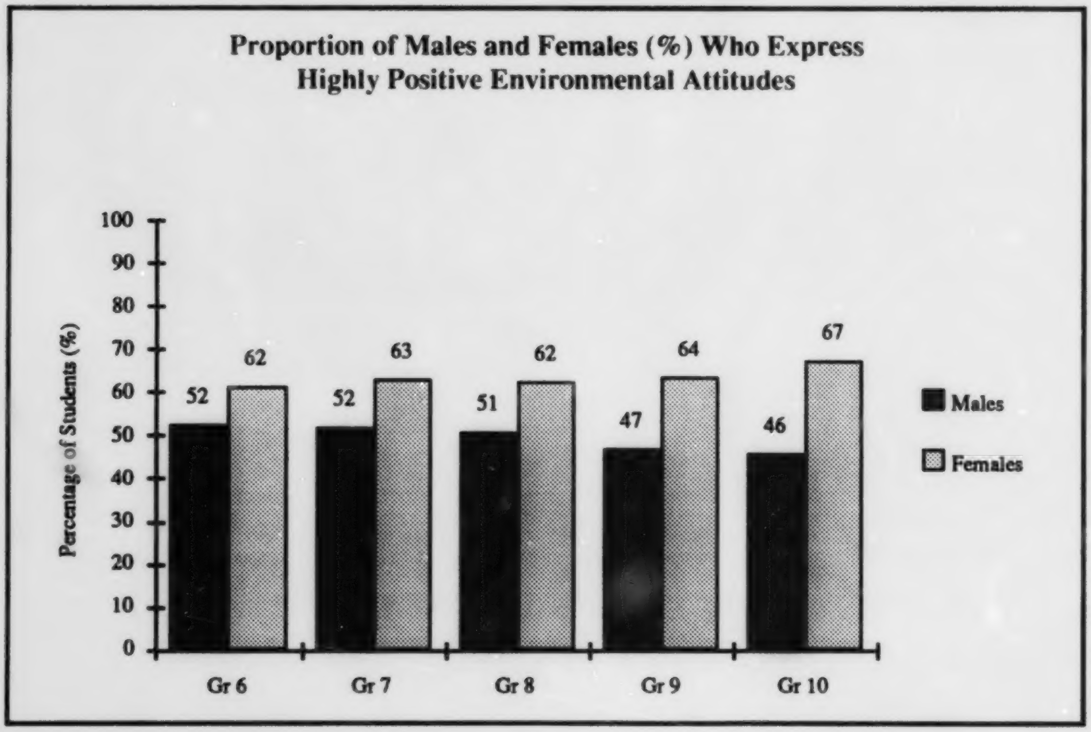
The one major exception to the otherwise environmentally "friendly" attitudes of students came on an item, shown in the graph below, which asked them whether they believed that highway speed limits should be made lower to conserve gasoline. On this item, students tended to go against their expressed concern for the environment and resources. Perhaps it is learning from society at large, or perhaps, since the students tend to disagree more as they get older, it is their love of speed and excitement as they approach the age where they themselves will drive, that overrides their usual concern for a specific environmental issue.

Proportion of Students (%) in Each Response on the Item
"Highway speed limits should be made lower so that we can save gasoline"



ATTITUDINAL GENDER DIFFERENCES

On almost all of the attitude scales there were no significant differences between males and females, with one outstanding exception. Females are more strongly positive than males in the area of environmental issues, although both males and females in general hold positive environmental attitudes. These differences tend to become larger as students get older.



ATTITUDINAL CHANGES OVER TIME

The biggest attitude changes over time are seen with respect to environmental issues. Since 1986, students have developed more positive environmental attitudes. For instance, responding to the statement that *Factories should be required to reduce smoke pollution even if prices go up*, 86% of 1991 Grade 10 students either agreed or strongly agreed, compared to only 76% in 1986. It is probable that media attention on these kinds of issues in today's society and increasing attention that these issues are receiving in school are contributing to these attitudes. A similar change in attitudes toward specific science issues has also been seen. For example, the statement that *Scientists should conduct experiments on live animals if they think people will be helped*, had 47% of the 1991 Grade 10 students disagreeing or strongly disagreeing, compared to only 33% in 1986.

ATTITUDE CONCLUSIONS

With the exception of attitudes toward a career in science, students in the Public Schools of British Columbia appear to be satisfactorily reaching the affective goals as stated in the Curriculum Guides. Although the results are generally satisfactory, we should not become complacent in trying to instill positive attitudes about science and science-related issues. In fact, there should be a renewed dedication to this very important area. As we approach the 21st century, it will be critical for students to have positive attitudes toward science, science careers, and environmental issues.

STUDENT ACHIEVEMENT

The Interpretation Panels examined the results of the student achievement instruments for each of the focus grades of 4, 7, and 10, representing the cumulative effects of education up to and including that grade. Using a formal procedure, they rated the results for each objective and goal on a five-point scale of ***weak (W)***, ***marginal (M)***, ***satisfactory (S)***, ***very satisfactory (VS)***, or ***strong (ST)*** based upon how the students did in relation to expectations. Items were then clustered together under the goals and objectives of the *British Columbia Science Curriculum Guides* and, based on consensus, overall ratings were assigned for each goal and objective.

The Interpretation Panel members who judged the results were quite satisfied with students' achievement in the area of the processes of science. However, there appears to be some concern in the area of factual knowledge about science, particularly at the lower grades. Despite this concern, it is encouraging to note that by the time students are in Grade 10, their knowledge is judged to be quite satisfactory. This same pattern of more concern at the lower grades and general satisfaction by Grade 10 has been seen in previous assessments. Perhaps one of the problems is the very high expectations, perhaps overly so, that have traditionally been expressed by members of the Interpretation Panel for Grade 7 students.

Some science educators maintain that as long as students understand the processes of science, much of the knowledge can be obtained as needed or desired. Also in our modern world of exploding information, facts can be easily obtained by "looking them up", often in large data bases. However, science processes cannot be "looked up"; the processes must be practised and understood. If one takes the view that knowledge of facts is of paramount importance, the weaknesses expressed at the lower grades are basically alleviated by the time students reach Grade 10. The importance of both processes and content in science education cannot be overemphasized. Science processes cannot be learned devoid of content. However, the particular content and concepts that provide opportunities to apply scientific processes might vary according to the local environment of the school and the previous experiences of the students.

The one weakness identified at Grade 10 at this time is in the area of "Rational Thinking" (the ability to look for natural causes of events). In this area, students could benefit from having opportunities to apply their scientific knowledge to solve meaningful problems which search for natural causes of events.

Interpretation Panel Ratings for Goals and Objectives

Goal/Objective	Grade 4 (Primary)	Grade 7 (Intermediate)	Grade 10 (Jr. Sec.)
Science Processes Overall	S	S	S
Observation	S	—	—
Classification	S	S	ST
Quantification	M	—	S
Communication	VS	VS	S
Drawing Inferences	VS	—	VS
Prediction	—	S	—
Interpreting Data	—	S	VS
Defining Operationally	—	—	ST
Identifying and Controlling Variables	—	VS	ST
Experimenting	—	W	VS
Formulating Models	—	S	—
Laboratory Skills	—	—	M
Safe Procedures	S	M	—
Locating and Processing Information	VS	M	—
Methods of Problem Solving	S	—	M
Scientific Knowledge Overall	M	M	S
Knowledge of Earth Space Sciences	S	S	—
Astronomy/Space Science	—	—	VS
Changes in the Environment	—	—	M/W
Knowledge of Life Sciences	M	S	—
Life Functions	—	—	M
Ecology and Resource Management	—	—	S
Knowledge of Physical Sciences	M	S	—
Changes in Matter	—	—	S
Energy	—	—	S
Total Knowledge	M	S	S
Scientific Vocabulary	M	M	VS
Relations among Scientific Disciplines	M	—	S
Nature of Science	S	M	S
Applications and Limitations of Science	S	VS	S
Knowledge of Safety	S	M	S
Higher-Level Thinking Overall	S	M	S
Creativity	S	S	M
Rational Thinking	M	—	W
Critical Thinking	VS	M	VS
Solving Abstract Problems	—	S	VS

— =not tested at this level; W=Weak; M=Marginal; S=Satisfactory; VS=Very Satisfactory; ST=Strong

WHAT SCIENCE CAN STUDENTS DO?

To focus on what students can do in science, a different approach was also undertaken with the assistance of the Interpretation Panels. The goal was to provide a set of anecdotal descriptors for six categories of performance at each grade and to identify the proportion of students that was likely to be at each performance category.

Briefly, the process involved:

- calculating a statistical estimate of the degree of difficulty of each item;
- rank ordering the items according to their difficulty; and
- dividing the items into 6 categories according to their level of difficulty.

For each grade level, Category 1 items are the least difficult for students and Category 6 items are considered the most difficult. After the items had been clustered in this way, the interpretation panels examined each set of items and made judgements about the types of scientific knowledge and skills students had to exhibit to perform successfully at each category level. It should be noted that almost all of the students in the entire population can do many of the tasks and skills listed at all of the levels, at least some of the time, under certain conditions. However, for each category, the students in that category can do the presented tasks and skills more consistently over a greater variety of contexts. The ability of any student to perform at any category level presumes that the student has the ability to achieve the knowledge and skills at any of the categories below it as well.

The descriptions of each of the achievement categories for each of the levels are presented on the following pages. Following each of the sets of descriptions is a figure which displays the percentage of students at each grade, as assessed in May of the school year, who can do the skills and possess the knowledge of each of the categories for the level.

LEVEL 1 - GRADES 3, 4, & 5

ACHIEVEMENT CATEGORY 1 - (99% of Grade 4 students)

These students were able to demonstrate precision of observation and to discriminate between actual observation and inferences. They also possessed a fairly sophisticated science vocabulary and were able to choose appropriate safety procedures when presented with acceptable alternatives. These students demonstrated a knowledge of the law of gravity in relation to air pressure and resistance, and they knew the metric symbol which is appropriate for measuring area.

ACHIEVEMENT CATEGORY 2 - (93% of Grade 4 students)

In addition to the above, these students evidenced a greater awareness of spatial relationships; they were more capable of applying specific knowledge of scientific concepts in life sciences and in physical sciences. They had better demonstrated the ability to draw inferences when dealing with abstract information, and had a better ability to classify using two attributes. They were more able to choose the appropriate procedures to test a hypothesis, and were more able to use sampling, estimating, and problem-solving methods using all units of measure.

ACHIEVEMENT CATEGORY 3 - (71% of Grade 4 students)

In addition to the above, these students were more able to understand and apply vocabulary pertaining to scientific principles and the environment. These students better understood the nature of science, including basic elementary science methods, laws (buoyancy, bacterial decay, plant reproduction, pressures), and processes. These students were better able to use the metric system to measure.

Achievement Category 4 - (37% of Grade 4 students)

In addition to the above, these students were more able to draw conclusions based on a study of drawings and/or diagrams of familiar objects. They showed a better ability to read and interpret displayed data in maps and charts as well as picto, bar, and circle graphs. They could better solve problems based on experience. These students could better recognize similarities and differences of animals and shapes, and classify them. They had a better knowledge of appropriate reference materials, basic vocabulary of life sciences and animals, and cardinal directions. They were more able to use the metric system to measure time, length, and temperature. They were also better able to recognize symmetry in natural objects and letters.

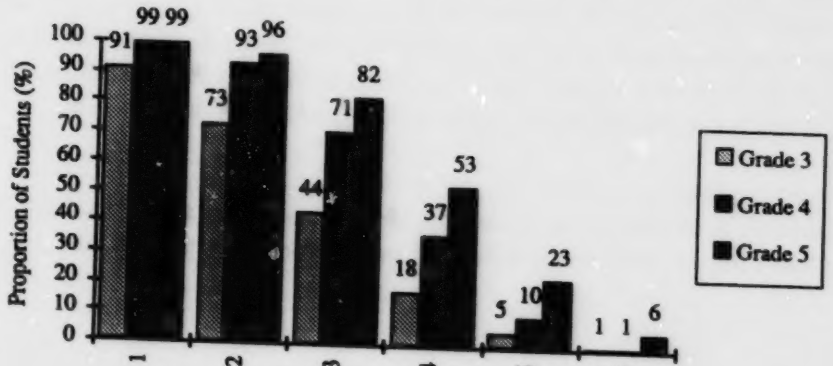
Achievement Category 5 - (10% of Grade 4 students)

In addition to the above, these students were more able to sequence familiar objects based on pictorial evidence using sorting and patterning; could better demonstrate a knowledge of personal safety in potentially dangerous situations; were more able to draw inferences based on past experiences through pictures and short texts; were more able to select information from a tally sheet, a bar graph, and pictures; were more able to observe characteristics based on pictorial evidence; and showed a beginning knowledge of weather, familiar animal defense mechanisms, perspective, and sound.

Achievement Category 6 - (1% of Grade 4 students)

In addition to the above, these students were more able to use details of their previous experiences to arrive at appropriate conclusions in complex situations; to sequence at a concrete level; to identify and discriminate amongst the senses; and to identify detailed similarities and differences of familiar objects.

Proportion of Level 1 Students (%) in Each Achievement Category
(See above for descriptions of categories)



LEVEL 2 - GRADES 6, 7, & 8

ACHIEVEMENT CATEGORY 1 - (93% of Grade 7 students)

These students demonstrated awareness of personal fire safety, had a knowledge of some safety symbols, and understood the relationships between human senses, e.g., taste/smell. They understood electrical conductivity and could identify the cardinal compass points.

ACHIEVEMENT CATEGORY 2 - (91% of Grade 7 students)

In addition to the above, these students were more able to demonstrate basic sequencing, classifying, communicating, data interpretation, transferring, and reading skills. They were more able to use these skills to demonstrate basic interpretation of sample tally charts, data charts, classroom keys, and pictorial representations. These students also possessed additional basic knowledge in the areas of lab safety, personal safety, scientific method, and earth sciences.

ACHIEVEMENT CATEGORY 3 - (66% of Grade 7 students)

In addition to the above, these students better showed an ability to interpret data from a variety of tables, charts, bar and line graphs, legends, diagrams, dichotomous keys, and climatic maps. They could better understand and apply the basic scientific method with controlled variables, hypotheses, experimental designs, and conclusions. They also had a more extensive knowledge of basic, common scientific terminology.

ACHIEVEMENT CATEGORY 4 - (31% of Grade 7 students)

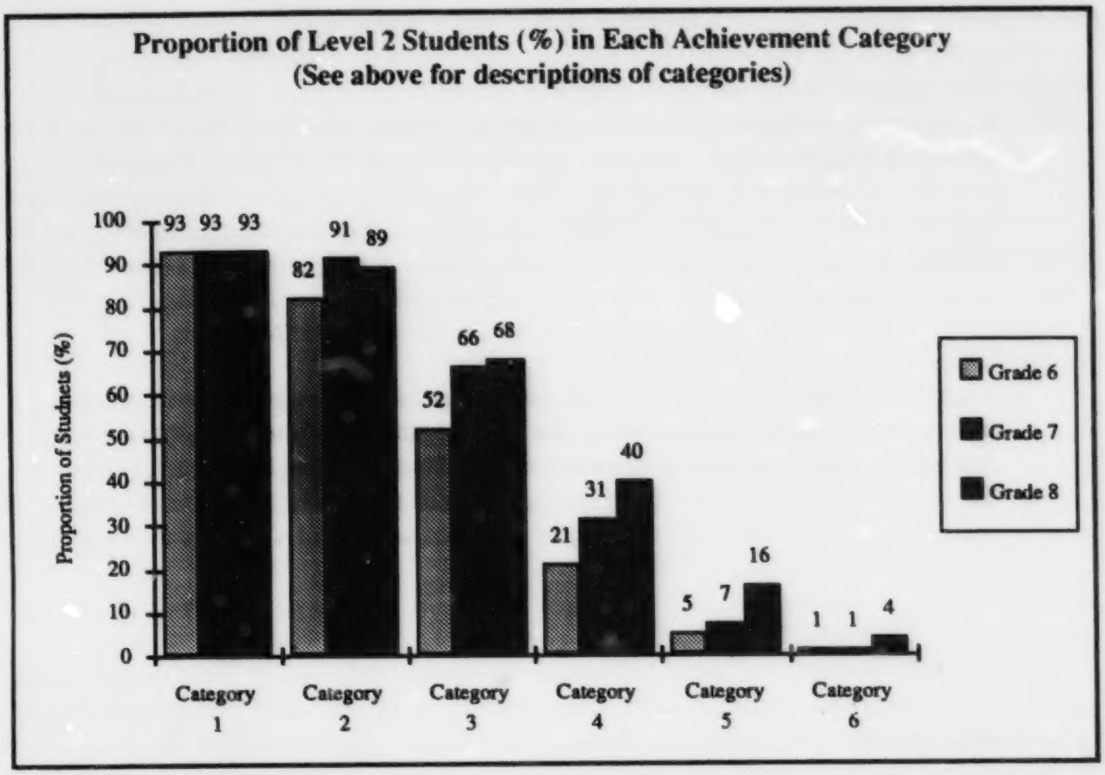
In addition to the above, students at this level were more able to demonstrate advanced understanding of controlling variables, testing hypotheses, interpreting data, and drawing inferences. They had a greater and more diverse knowledge of scientific topics such as photosynthesis, energy transformation, conductivity, simple machines, and solutions. These students could better extend generalizations and relationships, and could better apply this knowledge to real life situations and experiences. They could also better utilize a modification of the scientific process, resulting in more sophisticated scientific inquiry.

ACHIEVEMENT CATEGORY 5 - (7% of Grade 7 students)

In addition to the above, these students demonstrated a greater ability to select and interpret information from a variety of sources including dichotomous keys, pictorials, and grids. They could better synthesize and evaluate this information in order to solve problems, make decisions, and apply critical thinking abilities.

ACHIEVEMENT CATEGORY 6 - (1% of Grade 7 students)

In addition to the above, these students showed a stronger ability to recall terminology and had a highly specific knowledge of safety procedures used in labs.


Proportion of Level 2 Students (%) in Each Achievement Category
(See above for descriptions of categories)
Proportion of Studnets (%)
100
90
80
70
60
50
40
30
20
10
0
93 93 93
82 91 89
52 66 68
21 31 40
5 7 16
1 1 4
Category 1
Category 2
Category 3
Category 4
Category 5
Category 6
Grade 6
Grade 7
Grade 8

LEVEL 3 - GRADES 9 & 10

ACHIEVEMENT CATEGORY 1 - (98% of Grade 10 students)

Students in this category demonstrated basic knowledge about things that are reinforced outside of school settings such as the four basic food groups and the correct procedures to follow in event of an earthquake. They were able to accurately read, interpret, and decipher numerical values from simple measuring devices and tables, and could read a classification key and a simple schematic plan. They knew that scientific laws are derived from experimentation.

ACHIEVEMENT CATEGORY 2 - (87% of Grade 10 students)

In addition to the above, these students knew more laboratory safety procedures and could better recall basic knowledge such as the spectral components of light, that the sun is a star, and the degradable nature of certain wastes. Students could better interpret straight-line graphs and more readily apply a simple formula to solve word problems. They also demonstrated a better understanding of the need to control variables in a scientific experiment.

ACHIEVEMENT CATEGORY 3 - (61% of Grade 10 students)

In addition to the above, these students also showed greater curriculum-based knowledge in the areas of electrical circuitry, planet rotation, sedimentation and erosion, hazards of nuclear waste, and human reproduction. They also demonstrated a better understanding of the particle nature of matter and the difference between concepts of mass and weight. Students in this category were more able to recognize and understand the components of chemical formulae, and were more able to draw logical conclusions from data presented in a variety of formats, e.g., graphs, tables, and diagrams. They could better define and differentiate between components of the scientific method, knew, to a greater extent, the role of controlling variables in a controlled experiment, and showed greater insight into the process of drawing a valid conclusion.

ACHIEVEMENT CATEGORY 4 - (29% of Grade 10 students)

In addition to the above, these students also exhibited, to a higher degree, specialized curricular knowledge in areas such as the functions of the body, cell division, density, plate tectonics, and chemical formulation. They more readily recognized the integrated nature of science, better demonstrated the ability to draw relationships between principles, and could better apply scientific laws to explain new situations. They demonstrated, to a higher degree, the ability to integrate mathematical and scientific concepts to solve word problems involving simple machines and Ohm's Law, and could more accurately interpolate a non-linear graph. They could better apply skills of reasoning in order to make a critical interpretation of scientific data, better classify unfamiliar objects, more readily make inferences about new situations, and better evaluate experimental procedures.

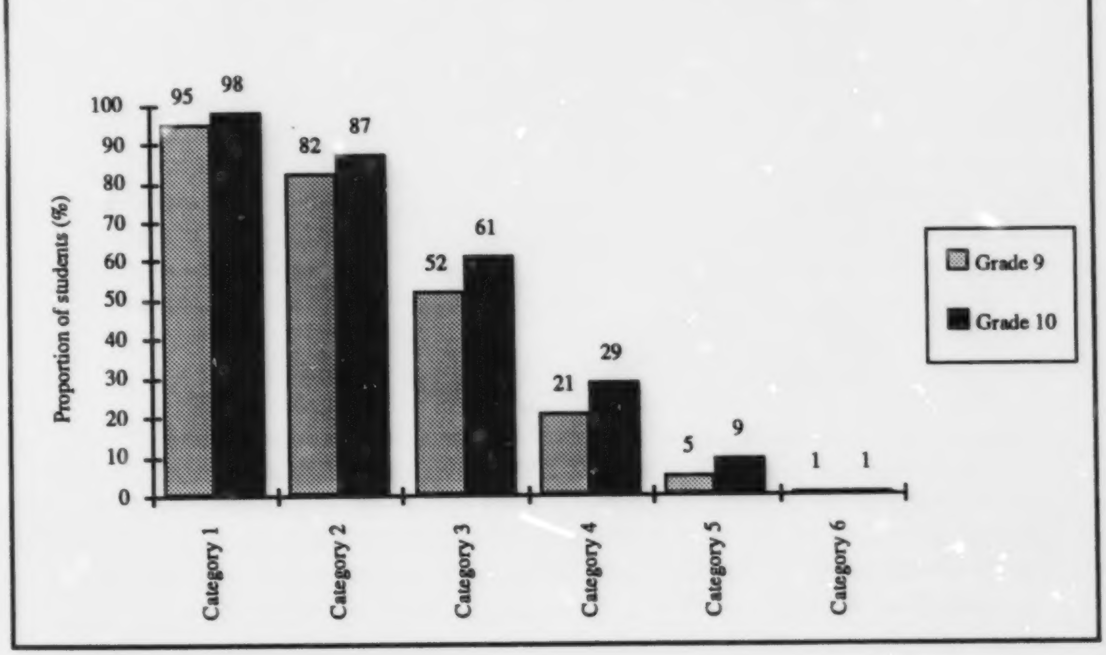
ACHIEVEMENT CATEGORY 5 - (9% of Grade 10 students)

In addition to the above, these students demonstrated a greater ability to recall and apply specialized curriculum-based knowledge in areas of weather formation, pH levels, drug effects, crystal formation, thermal expansion, photosynthesis, nutrition, genetic probability, Law of Conservation of Mass, and the Atomic Theory in order to solve complex problems. They could also better solve problems related to radioactive half-life and were more able to interpret electrical circuit and geological cross-section diagrams. They understood, to a greater degree, technical and scientific terminology, and better recognized that scientific research must be repeatable in order for theories to be validated.

ACHIEVEMENT CATEGORY 6 - (1% of Grade 10 students)

In addition to the above, these students exhibited a greater knowledge about some concepts which are not widely taught, such as the extrapolation (extension) of a non-linear graph and refraction of light through a lens.

Proportion of Level 3 Students (%) in Each Achievement Category
(See above for descriptions of categories)



ACHIEVEMENT GENDER DIFFERENCES

Traditionally, science has been one of the areas where testing has shown a higher performance by males in most areas. However, over the past assessments, there has been a decrease in the differences. This assessment has shown that there is now very little overall difference between the performances of males and of females in science in general. However, significant differences in performance exist in particular areas and on particular items.

Females tend to perform higher on many of the process skills, and on items involving conceptual planning, abstract and critical thinking, and the nature of science and safety.

Males tend to perform higher on items involving measurement, lab techniques, numerical problem solving, earth/space science, and energy topics, particularly electricity. Overall, the very minor differences that seem to persist from Grades 3 to 10 are in the areas of Skills and Processes (favouring females) and Scientific Knowledge (favouring males).

ACHIEVEMENT CHANGES OVER TIME

Results of Common Items - 1986 and 1991

Level	# of Common Items	1986 Mean	1991 Mean	Change
Grade 4/Level 1	48	64.2%	60.9%	-3.3%
Grade 7/Level 2	24	55.3%	52.5%	-2.8%
Grade 10/Level 3	12	54.3%	53.4%	-0.9%

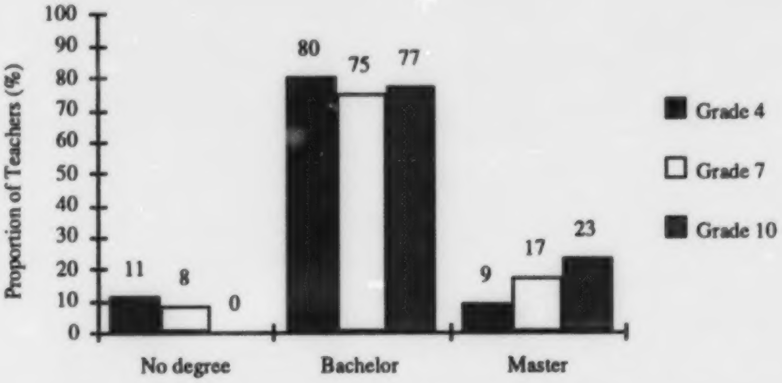
By using some identical questions on each assessment of science, it is possible to indicate how student achievement is changing over time in the province. The assessments of 1982 and 1986 showed gradual improvement and increases in student achievement over previous assessments. These increases have been in the range of two to four percent for each assessment. The 1991 assessment has shown that the increases we have seen in the previous assessments are not being maintained and there are indications that student achievement in science is going down.

Again, it should be noted that the evidence of any existing problems in science education in 1991 is stronger at the lower grades and less obvious by Grade 10. When interpreting these results, it is important to consider the climate of the education system in general during the 1990-91 school year. Job action related to legislation and contract negotiations occurred throughout the system. Many teachers indicated that they believed that major initiatives such as the *Year 2000*, and other initiatives such as Learning for Living, Computer Literacy, Block Parent Programs, and Abuse Prevention Programs have demanded teacher time and attention. As well, some of these initiatives have increased pressures on time allocated to the traditional curriculum. This is consistent with the comment, "Pressure is also directed from sources outside the school system to modify or restructure the school curriculum to make room for new courses or topics which are seen by their proponents to be sufficiently important and timely to warrant inclusion." (*A Legacy for Learners*, British Columbia Ministry of Education, 1988, p. 78). In addition, "Considerable pressure is placed on individual schools and the system as a whole to make room in the curriculum for new programs and initiatives, . . . " (*Ibid.*, p. 81). Since the time required for most of these new programs is most likely not taken from the "core" areas of language arts and mathematics, it follows that time would likely be taken from other subjects. While all of the additions and reforms to education are most certainly important, educators must establish priorities. If science is important, students must be involved with the processes and concepts of science, and time and resources must be devoted to the teaching of science.

TEACHERS OF SCIENCE IN 1991

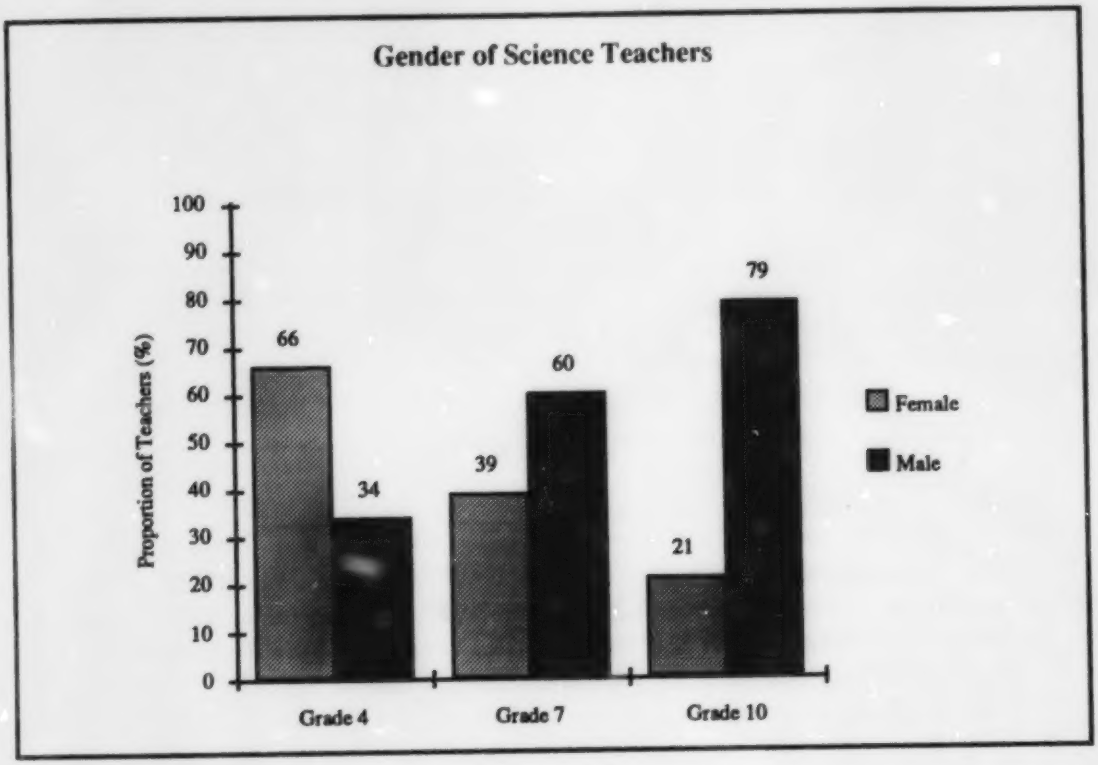
The results of the Teacher Questionnaire indicate that the teaching of science in British Columbia schools is generally conducted by well-educated and experienced teachers who enjoy teaching science and generally use a broad and varied array of practices and strategies in their classrooms. The age and teaching experience of science teachers is consistent across the three grades: over two-thirds of the teachers are in the range of 30 to 50 years old; most teachers have been teaching for more than ten years, and most have taught science for more than 6 years.

Educational Background of Science Teachers



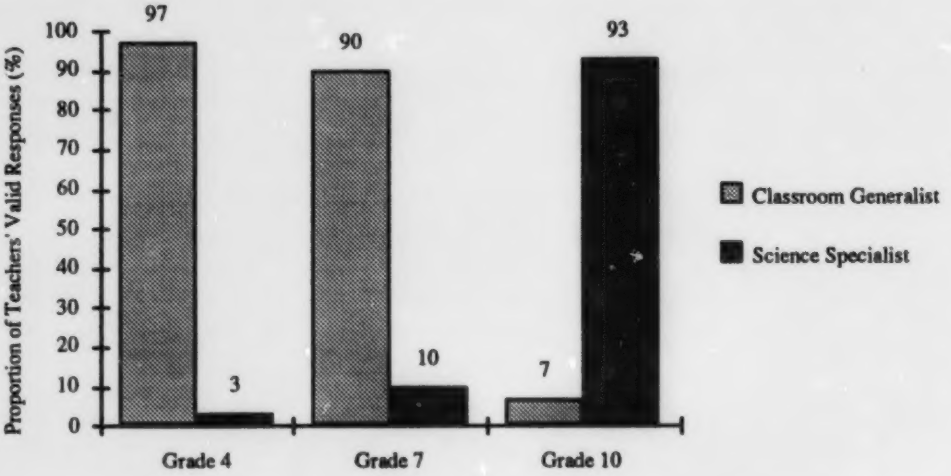
GENDER OF TEACHERS OF SCIENCE IN 1991

A notable variation in the teacher population across grades is in terms of gender. Grade 4 teachers of Science are predominantly female whereas teachers of Grades 7 and 10 Science are predominantly male.



There is an important distinction in the way in which the responding teachers view themselves. Most Grades 4 and 7 science teachers view themselves as classroom generalists, whereas most Grade 10 science teachers view themselves as science specialists. This accurately reflects the reality of how, and by whom science is usually taught in British Columbia.

Science Teachers' Views of Themselves as Science Specialists or Classroom Generalists



Instructional Practices and Strategies

Results indicate that a wide array of instructional strategies are employed by most teachers of science. However, data from the student questionnaires indicated that there is presently little use of library materials, computers, or field trips to augment the science program. In these situations, resources may be a problem. Written comments indicate that most teachers vary the instructional practices to suit the topics and objectives of the unit under consideration. A comment that typifies teacher perspective on instructional strategies and practices comes from a grade 10 teacher: "I feel variety is best and hands-on in science is a must." Teachers suggest that increasing in-service opportunities in the area of instructional strategies and practices would be most welcome and beneficial.

Co-ordination of Science in Schools

Teachers indicate a general lack of science coordination within the schools and the written comments contained many notes saying that a science coordinator would be a valuable addition to both the school and the district. The need for a science coordinator is likely to be even more important in the future as *Year 2000* initiatives are implemented. (For more information on this topic, please see "The Context for Science Component".)

RESOURCES AND FACILITIES

Teachers of Grades 4 and 7 science report that they found the science equipment for student use and demonstrations, and laboratory facilities to be inadequate. In contrast, the majority of Grade 10 teachers report the availability of science equipment and lab facilities to be adequate. Most teachers report having preparation time and budgets for science supplies and field trips, but most view the available allocations as inadequate.

PROFESSIONAL DEVELOPMENT

Teacher comments strongly point out that more in-service in the form of workshops, particularly with a "hands-on" approach, is needed for science educators. There appears to be a definite lack of opportunities for teachers to participate in science workshops. A number of Grade 4 teachers commented that those workshops that were available had a focus on the *Year 2000* to the exclusion of science. This perspective is typified by the comment: "I would like to do more [science] in Pro-D but most time recently has been devoted to meetings about *Year 2000*."

SPECIAL NEEDS STUDENTS IN SCIENCE

Most teachers indicated that they did have special needs students in their class, but most teachers also indicated that no resources were provided specifically for these special needs students. The responses indicate that in those classes with special needs students, the students participated in most class activities. The written comments pointed out the difficulties in handling science classes that include special needs students who require help.

SAFETY

Teachers were relatively consistent across grades in regard to safety concerns. Written comments from Grade 4 and 7 teachers indicate that safety concerns were generally attended to by ensuring that the activities of the students in science were limited to those that were safe. Grade 10 teachers, likely because of the increased use of laboratory activities, express more direct safety concerns. One comment that captures the thought is: "I feel a lot of the time I am jeopardizing my own and my students' safety because of lack of basic equipment–eye wash stations, etc."

STUDENT EVALUATION

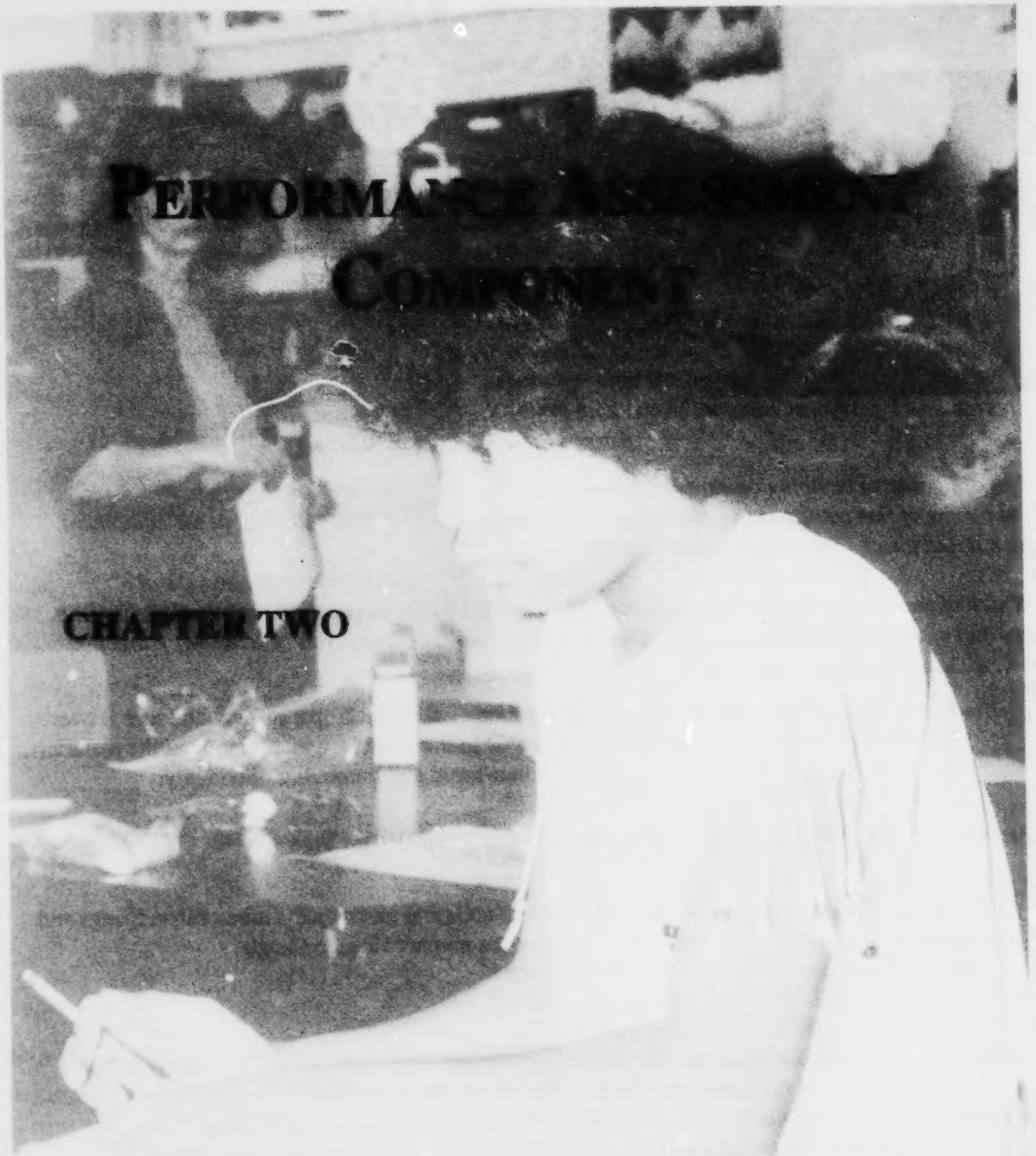
Science teachers, at all grades, generally assign letter grades to students. Most wrote descriptive reports on students (particularly Grade 4 and 7 teachers). Student results were based upon the use of a wide array of classroom procedures (as opposed to school or district level tests) aimed at assessing student achievement on all the goal areas of the science curriculum.

COURSE MATERIALS

Grades 4 and 7 teachers were asked about their use of various printed materials in their science class. Most teachers indicated that they use a combination of programs and their own ideas to teach their science program. Exploring Science, STEM, the Materials-Based Option and Focus on Science are used, at least in part, by most teachers.

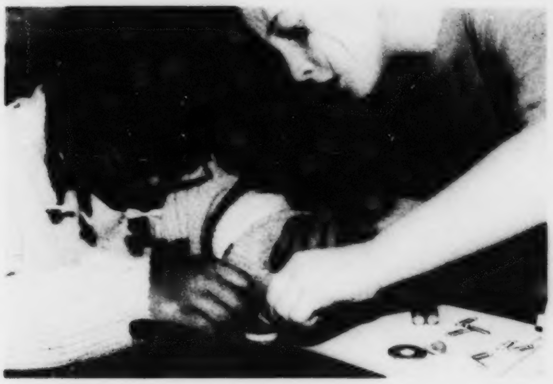
TEACHER QUESTIONNAIRE CONCLUSION

The teachers of science in British Columbia appear to be experienced and concerned about science education. However, there appears to be a growing concern over the development and provision of science in-service programs for teachers coupled with diminishing resources for science materials and facilities, and the need for science coordinators at the district and school levels. These issues are of concern and must be dealt with if science education is to maintain an important place in the education of our children.



PERFORMANCE ASSESSMENT COMPONENT

CHAPTER TWO



Elizabeth and Paula arrive ahead of schedule, walk to the desk, on which all the materials are arranged, and sit down at my invitation. They sit, unsmiling, upright, scanning the desk top, the materials, and occasionally look at me:

"You are going to be doing an experiment today. Look at the equipment on the table. You may want to use some of this equipment in your experiment. Spend 2 or 3 minutes looking at the equipment, touch it and check that you know how it works."

"Which of the three magnets in front of you is strongest? While you answer the question, I will sit here and make some notes about what you do. I hope I do not disturb you. Please work together and talk to each other."

Silence.... Both pick up a magnet and turn it over slowly in their hands, while looking at the materials, sullen-faced and unmoving. Suddenly:

Elizabeth: *"I know what to do. Let's see how many balls they will pick up."*

Paula nods and picks up the tube of iron filings and puts the magnet close to the glass.

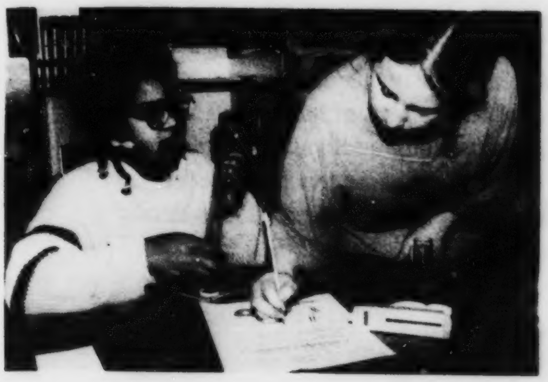
Paula: *"Hey! Look! It stands up."*
Elizabeth: *"It holds 4 balls, the red one holds 4."*
Paula: *"It stands up, it stands up like hair. Give me the silver one. Look, it is not good, the graphite does not stand up as much. The silver one is no good."*
Elizabeth: *"Let's try the black one.... It holds more, it holds 5. The black one wins."*
Paula: *"It picks up more balls."*
Elizabeth: *"Let's try something else."*

The pair repeat the testing of the red and black magnets using steel balls, paper clips, nails, small washers and steel cubes. They are puzzled as sometimes one magnet holds more objects and sometimes the other holds more.

Paula: *"Which magnet wins more?"*

Elizabeth looks puzzled and is silent.

Paula: *"Which magnet holds more things like balls, clips, and nails? Which magnet wins more?"*



They review their work and decide that black wins over red, 4 to 2. Black holds more washers, balls, paper clips and steel cubes. This review is carried out from memory of the previous tests. There are no written records.

Paula: *"Black's stronger. Yes, definitely it's stronger."*
Elizabeth: *"Yes, and silver is no good, and red is second."*

"You have decided," I say, and they nod and chorus yes. *"It's black then, and you both agree."*

Paula: *"Can we take the graphite (iron filings) out of the bottle?"*

"Sure," I say, and off they go, enjoying the playful experience of a particulate material that behaves like a liquid. Eventually we tidy up and the children leave. As they reach the door Elizabeth asks,

"Was the black magnet really stronger?" and Paula chimes in. *"What is the right answer anyway?"*

The above vignette typifies one type of situation that was used in the performance assessment component to obtain information about the ways in which students interact with materials to solve problems.

teacher:

How did you like doing this study?

girl:

I also like that we got to do it our own way and not some pasifick way and thats what I liked

boy:

I was great! I didn't have to bore my mind out from a teacher giving an explanachon

girl:

I liked station 12 because it was cool to see the bugs craling around. It was cool because they were alive

boy:

Because it was fun and we got to miss some school

THE STUDENTS AND THE TEACHER ADMINISTRATORS

Students were selected from schools in all regions of the province to participate in this component of the Science Assessment. About 110 students at each of the three grade levels took part in the stations tasks and about 55 pairs of students completed the investigations tasks. Two teachers from each of the 18 participating school districts took part in a 3 day workshop in April, 1991 to prepare to administer the tasks in their own districts. They administered these tasks in May, 1991 to students in the sampled schools (which, in all cases but two, were not their own school). In July these same teachers met for three days to analyze and interpret the results of the students' responses to these two tasks.

INDIVIDUAL INVESTIGATIONS

There were two different types of open-ended investigations–one inquired into the relative strength of magnets, while the other asked the students to identify which of three different kinds of paper towelling "held the most water." These same two investigations, which usually occupied a pair of students for 40 to 60 minutes, were used with students at Grades 4, 7, and 10. The selection of these two investigations resulted from extensive pilot studies with four investigations. Several criteria were used in this selection process. A good investigation is understandable, is intrinsically interesting, and is challenging to students at all three grade levels.

PERFORMANCE ON THE INVESTIGATIONS

In the investigations the students, working in pairs, were assessed on their planning and conduct of their work as they answered a question, using a given set of materials. Two investigations, "Paper Towels" and "Magnets," were used with Grade 4, 7 and 10 students.

In the "Paper Towel" investigation, the students were given 3 types of paper towels and were asked, "Which kind of paper will hold the most water?" They were provided with funnels, graduated cylinders, beakers, scissors, a balance, a tray, stop watch, eye dropper, and a calculator.

In the "Magnets" investigation, students were given 3 magnets of the same size and mass but differing in strength. They were asked "Which magnet is strongest?" and provided with materials: washers, nails, steel rods, steel balls, a spring balance, plasticine, and a ruler.

The data obtained from the students' performance on these investigations, along with the very positive teachers' interpretations of this performance, lead us to conclude that:

- student performance at all grade levels in planning, developing a measuring strategy, interpreting data, and reporting results was satisfactory for both investigations.

Students can design and implement procedures when presented with materials and an operational question. The teachers valued the enthusiasm and abilities of the students and were pleased and surprised by the performance of the younger students.

Grade 4 students do more estimating while Grade 7 and 10 students use a wider variety of measuring strategies. Computing a result by the mathematical manipulation of numbers is absent in Grade 4 and is rare in Grades 7 and 10. The idea of measuring magnetic force exists at all three grade levels. Students pay attention to those things they know will affect the outcomes of their work. Many Grade 10 students know about the poles of magnets and pay attention to which side of the magnet they use. Grade 4 students typically do not. Students pay attention to the similarity of objects used with different magnets, the volume of water used with paper towels, but typically disregard the dissimilarity in size of the paper towels.

Hence it is claimed that:

- student measuring strategies such as counting, linear measurement, weighing and estimating are common across the three grade levels;
- knowledge is important (students plan and execute a procedure based on their knowledge of how magnets or paper behaves);
- students at all grades can and do control those variables they know about.

Most students correctly identified the strongest magnet using the data they had collected and came to an appropriate conclusion as to which paper towel holds the most water. These results lead to the claim that:

- student interpretation of data is good at all grades, and outstanding at Grade 10.

One area in which there were indications of some weakness for the younger students was in the written documentation of their results. The younger students in particular may be disadvantaged by having to report their work in written or diagram form. However, the Grade 4 teachers anticipated this problem and required students to report orally as well as in written form, and while judging their students to have done well, they rated their overall performance in reporting their work lower than for other criteria of the performance assessment.

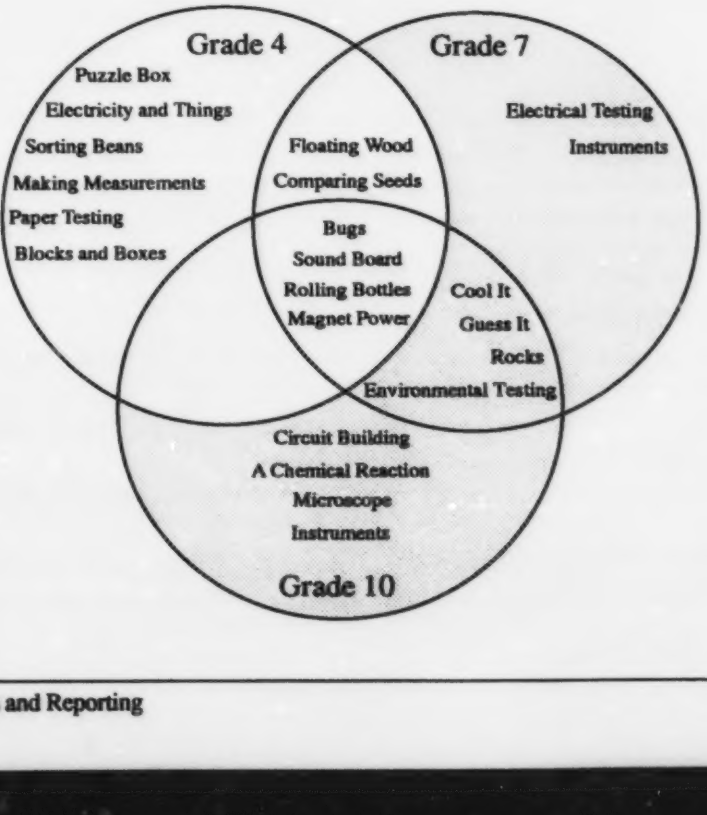
- Teachers, in general, were less satisfied with student reporting of results at Grade 4 and Grade 7; however, they judged Grade 10 students to have performed well.

The teachers' degree of satisfaction with student performance was similar for all three grades. This may be the product of age and grade appropriate criteria and standards developed by the grade-level teachers. That is, teachers judge younger children less stringently than older children. However, there is evidence that in the higher grades the influence of knowledge of magnets and testing seems to relate to a higher level of performance. Nonetheless, the results indicate that even the Grade 4 students have developed procedures and strategies for carrying out valid investigations.

- While there is variation in students' performance across any grade level, there is a striking degree of consistency in the criteria developed by grade-level teachers and their judgements of student performance.

STATION TASKS

Station Tasks


Grade 4
Grade 7
Puzzle Box
Electricity and Things
Sorting Beans
Making Measurements
Paper Testing
Blocks and Boxes
Floating Wood
Comparing Seeds
Electrical Testing
Instruments
Bugs
Sound Board
Rolling Bottles
Magnet Power
Cool It
Guess It
Rocks
Environmental Testing
Circuit Building
A Chemical Reaction
Microscope
Instruments
Grade 10

A set of 12 tasks, arranged in a station format, was developed for each of the three grade levels. These tasks consisted of a series of short-term, well-defined problems where the students used the materials laid out at the station to answer several questions provided on a response sheet. Students spent about seven minutes at one station and then rotated to the next station. Each student attempted six out of the twelve stations. Four of these stations, Bugs, Sound Board, Rolling Bottles, and Magnet Power, were used at all three grade levels, while several others were used at two different grade levels. The diagram on the previous page shows all the tasks for each grade level with the overlapping areas showing the common tasks.

As an example, a station used at Grades 4 and 7 called "Comparing Seeds" provided the students with a series of capped plastic vials containing a small quantity of similar seeds. Two of the vials, labelled "Group 1," contained fennel and oat seeds respectively. Two other vials, labelled "Group 2," contained allspice and black peppercorns respectively. Sunflower seeds were in another vial labelled "X," while yellow mustard seeds were in the final vial labelled "Y." The students were required to first identify any similarities between the two vials of seeds in Group 1 and Group 2, then place the seeds in vials X and Y into one of the above two groups, and give a reason for doing so.

girl:

I like doing this kind of study because the people make it fun and easy and because it TOATLY AWESOME.

boy:

Neat cause you could do it by your self

girl:

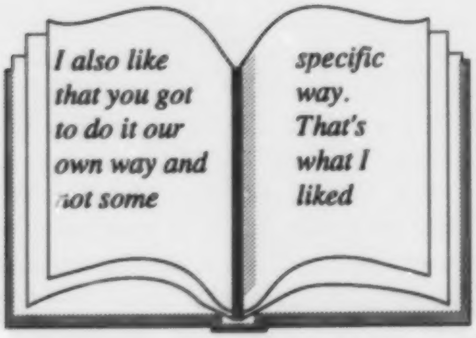
You learn. The reason I say you learn is because you get smart.

boy:

I felt really smart in some ways because I always thought I was dumb.

RESULTS FROM THE PERFORMANCE ASSESSMENT

Student performance on these tasks can be reported in terms of a description of what the students actually did or as an interpretation of that performance by the teachers who administered the tasks and coded the results. We refer primarily to the latter in this report because it provides a concise but comprehensive judgement of the students' performance. For each of the stations the teachers were asked to make one or two interpretations of each student's performance on a five-point scale of satisfaction.



I also like that you got to do it our own way and not some specific way. That's what I liked

PERFORMANCE ON THE STATION TASKS

In general the teachers' interpretations indicated that the Grade 4 students performed very well on the stations tasks. On 10 out of the 12 stations over 60% of the students received an interpretive rating of satisfactory or better. These very favourable ratings, combined with our analysis of what the students actually did on these tasks, lead us to conclude that the Grade 4 students were very proficient in their work with materials, and their abilities

- to make observations in different contexts,
- to classify objects,
- to draw inferences from their results,
- to make predictions based on their findings, and
- to communicate their results.

The only area of possible weakness identified in the performance of the Grade 4 students was their ability to communicate in writing what they found out.

At the Grade 7 level, 8 out of the 12 stations received a satisfactory or better rating for 60% of the students. As with the younger students, the Grade 7 students displayed considerable competence in their abilities

- to make appropriate observations,
- to classify living and non-living objects,
- to make appropriate inferences based on data,
- to make and justify predictions, and
- to communicate observations and results.

However, their performance on several of the stations revealed some weaknesses in addition to the above strengths. The Grade 7 students appeared to have some difficulties when asked

- to use some instruments to measure selected properties,
- to estimate such properties as mass, area, volume, and temperature, and
- to extrapolate from data in a table.

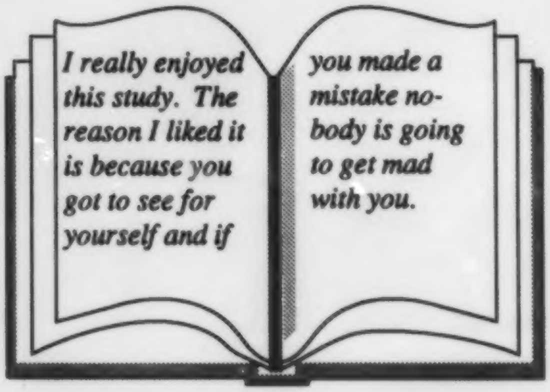
Overall, considering the information obtained from all of the stations, the grade seven student performance on the station tasks was satisfactory.

The interpretive data for Grade 10 rated student performance on 6 out of the 12 stations as satisfactory or better for 60% of the students. These data indicate some strengths and some weaknesses.

The pattern of performance observed in the earlier grades continued, showing the Grade 10 students competent in their ability
- to make relevant observations of phenomena,
- to use materials to construct solutions to a given problem,
- to make appropriate inferences from data,
- to use a classification system to identify particular objects, and
- to communicate the results of their findings in writing.

The results showed that there was an increased need for Grade 10 students to use specific content and procedural knowledge that would likely come only from the science classroom. For instance, two of the stations required quite specific knowledge of how to write a balanced chemical equation and how to calculate the magnification power of a microscope. From these results it would appear that many of the Grade 10 students in our sample either were not exposed to these curricular topics prior to the assessment or experienced considerable difficulty in understanding them. Yet on another station that required knowledge of electrical circuits, over 90% of the students were judged to be satisfactory or better on their ability to construct and draw these circuits. Regarding more general abilities, the Grade 10 students appeared to experience some difficulties when asked
- to estimate such properties as mass, area, volume, and temperature; and
- to provide scientific explanations for observed phenomena.

Considering the increased complexity of the tasks and the higher expectations of performance on the part of the teachers who interpreted the data, we judge these results to be satisfactory. We add, however, that these results may indicate that secondary students are not being provided with enough opportunities to become engaged in problem-solving situations where they are expected to use materials to investigate the problem and then theorize about the results of their inquiry.



I really enjoyed this study. The reason I liked it is because you got to see for yourself and if you made a mistake nobody is going to get mad with you.

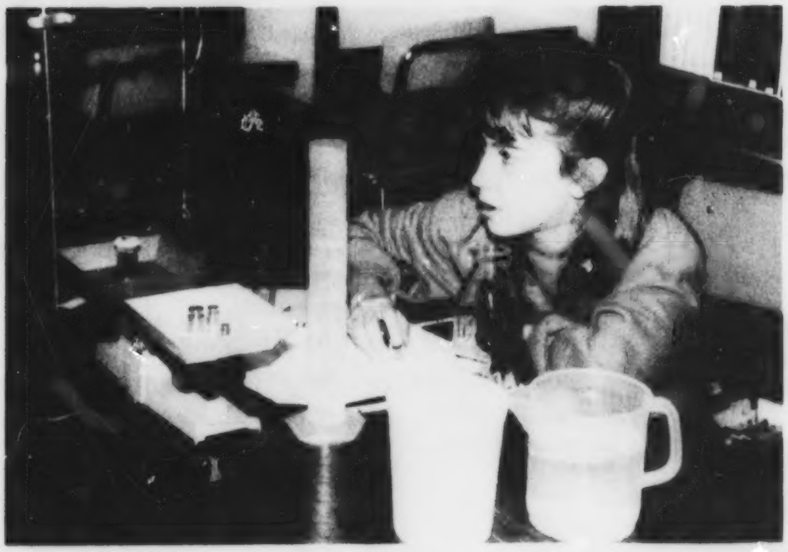
GENDER-RELATED DIFFERENCES

Gender-related differences in student performance have been present in varying degrees in previous assessments throughout the world. In many aspects of school science, such differences have become part of the folklore of assessment in science education. The tasks for this assessment component were developed to identify student approaches to experimental work in many contexts, and made use of materials that we would expect male and female students to encounter in their everyday experiences. The data from this component indicate that similarities in performance between females and males were more evident than the differences.

The measuring stations showed variations in performance where:

- 98% of Grade 4 females, as compared with 82% of males, showed a "satisfactory or better" level of proficiency in measuring tasks; and
- 34% of Grade 7 females, as compared with 58% of males, were considered to have performed at a "satisfactory or better" level of performance.

The differences between the Grade 4 and the Grade 7 measuring stations exist in the use of the measuring equipment. Many of the measuring devices found in the home such as measuring cup, tape, ruler, and thermometer were used in the Grade 4 station. The Grade 7 station made use of more scientific materials: graduated cylinder, stop watch, and two-pan balance, in addition to the tape, ruler, and thermometer used in the Grade 4 station. At the Grade 10 level teachers rated both female and male student performance on the measurement station at similar levels.



The performance of females and males on the station "Magnet Power" was also judged to be different at each grade level. For this station:

- at Grades 4 and 7 more females (67%, 76%) than males (54%, 56%) were judged to perform at a "satisfactory or better" level; and
- at Grade 10 more males (74%) than females (64%) performed at a "satisfactory or better" level.

These differences were evident in teachers' judgements of the students' abilities to develop a strategy and communicate their procedure. Perhaps the open-ended nature of the problem and its solution appealed to the younger females and showed in the quality of their responses, whereas the Grade 10 results may be related to experiences with the physics component of the junior secondary curriculum that could have differentially increased the males' knowledge and interest in magnetism.

Station 4, "Environmental Testing", produced a small gender difference at Grade 7, but at Grade 10 more females (75%) than males (58%) performed at a "satisfactory or better" level. The interests that females have shown in the environment are, we believe, a pointer to explain the differences in performance in this station. The abilities of males and females to measure and interpret pH values were similar. The quality of the females' explanations for the change in acidity of a lake was rated higher by the teachers.

SOME IMPRESSIONS

In conducting this assessment of performance we have been impressed by the responses of both teachers and students. Uniformly, teachers have been positive about what was being done and they were impressed by what their students did. The students liked to work with materials and work cooperatively in the investigations.

The teachers' positive response, we believe, is rooted in a rich understanding of professional practice, presenting a holistic view of scientific inquiry, relating science assessment to the goals of the curriculum, developing assessment procedures that are in concert with current ideas, and appreciating the intellectual involvement of their students in tasks which they see as significant and purposeful.

The positive response of students across all three grade levels is both heartening and instructive. Students recognize interesting and challenging activities in science, and they recognize their own abilities to work independently and cooperatively to construct meaning, and to make decisions. The students sharply contrasted these self-directed activities with the type of work they associate with school generally. Their message to us was clear and unequivocal: They would like more opportunities to work as individuals and in groups with hands-on materials.

We think it is appropriate to conclude this section of the report by presenting the voices of students. A sample of Grade 4 comments points in the direction that reveals potential and promise.

I really enjoyed this study. The reason I liked it is because you got to see for yourself and if you made a mistake nobody is going to get mad with you.

I also like that you got to do it our own way and not some specific way. That's what I liked best.

Neat, cause you could do it yourself.

I felt really smart in some ways because I always thought I was dumb.

LOOKING TO THE FUTURE

These considerations flow directly from the findings of the performance assessment component. While all students performed well, there are clear possibilities for the improvement of performance.

1. Given the students' demonstrated abilities and interest in these assessment tasks, students should be given more opportunity to generate questions and to seek answers from their own investigations.

    While we value the answers of set questions, we more highly prize the developing ability in students to ask their own questions for investigation. It is in the articulation and investigation of such questions that students develop a sense of inquiry which could be called scientific.

    We hope that opportunities would be made available for students to investigate and that their efforts would be valued. However, we also hope they would be assisted to become critical of what they do and of the conclusions they come to, and so become better performers of investigations.

2. Given that students do not report results well, particular attention should be given to this aspect of investigations.

    It is suggested that a wider variety of modes of representation than those used in this assessment be used. It is thought that students might profitably record their findings in writing, drawing, modelling, and verbal reporting to a teacher or fellow student. The use of audio and video recording might also be considered as ways to represent what has been found out.

3. Given the positive student response to these tasks, we would encourage teachers to use more of these types of performance tasks in their assessment procedures.

The particular tasks used in this component of the assessment, although limited in terms of content knowledge and abilities assessed, are models for use in conjunction with other assessment techniques.

4. Given the importance of content knowledge in the planning and execution of investigations, it is critical that the acquisition and use of relevant content knowledge be recognized and encouraged.

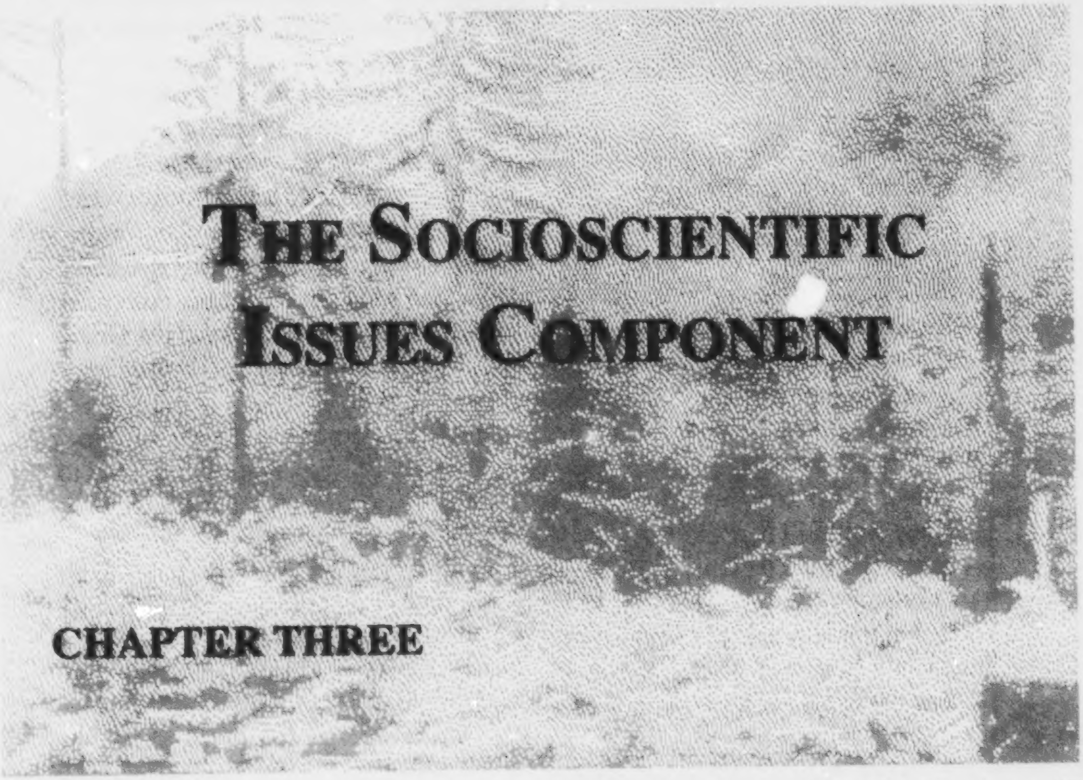
Student performance in both the investigations and with some of the stations indicate the important role of content knowledge in the students' abilities to generate good questions, to use fruitful strategies, and to develop appropriate interpretations of their data.

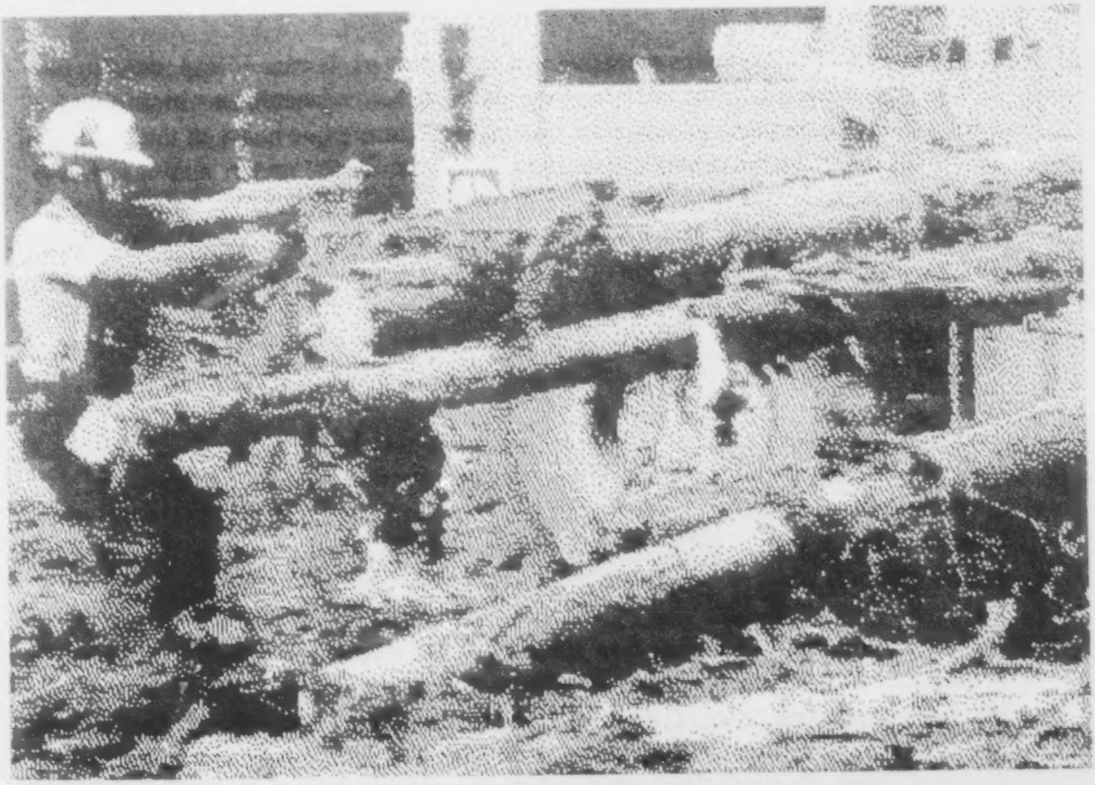
It seems to us that one of the primary differences in performance between Grade 4 students and Grade 10 students is the increasing sophistication of this knowledge base. Hence, we would encourage teachers and curriculum writers to provide students with many and varied opportunities to construct ever more powerful ways of looking at and thinking about phenomena in the student's natural environment.

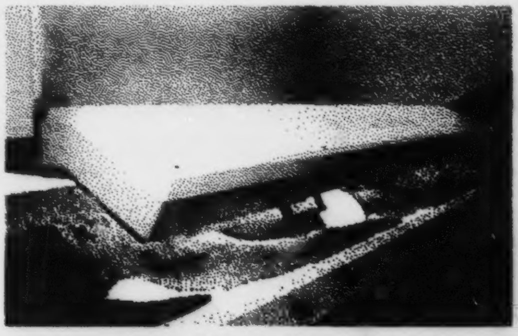
Students thrive on variety and it is in varying classroom teaching and assessment strategies that students will best learn and profit from their school experiences.

THE SOCIOSCIENTIFIC ISSUES COMPONENT

CHAPTER THREE







Wendy, a Grade 7 student in an interior school, came to class one spring day looking more tanned than she had the day before. Other students were impressed and asked her how she had achieved such a beautiful colour. Pleased with all the attention she was getting, she replied that she had tried out one of the numerous local tanning parlours. Over the next several weeks, many more of the Grade 7 students, particularly the girls, visited suntanning parlours and showed off what they considered to be a "healthy glow." Susan, however, was not convinced. She had heard that tanning could lead to skin cancer and decided to withstand the mounting peer pressure to "fake bake." In addition, she tried to convince her friends that what they were doing was risky and unnecessary. They wouldn't listen to her. She tried to enlist the support of visiting UBC researchers. "You have to talk to the other students in my class," she pleaded. "Perhaps they will believe you when you tell them that tanning is dangerous." The researchers mentioned this incident to the principal and class teacher. They had been unaware of the intensity of this issue among the students and had not explored it in class.

Students participating in this component of the science assessment responded to one of four socioscientific issues: forestry, use of animals in research, suntanning, and toxic waste. Researchers encountered this incident during one phase of the project. It illustrates the importance of eliciting and assessing students' understandings of, and responses to, socioscientific issues. The issue described in this incident is typical of the many complex public issues involving some aspect of science with which children and adults must frequently contend. The issues are personally relevant but they are also difficult to deal with because they involve conflicting principles. For example, in the incident described above, there is a conflict between the desire to fulfill socially defined standards of beauty and the desire to avoid risks of getting skin cancer.

These issues are also difficult to deal with because they may involve combining a variety of different kinds of knowledge, such as scientific, ethical, political, and economic. In addition, there are no right answers to these issues and decisions often have to be made with incomplete information. Increasingly, teachers are being asked to help students address these kinds of issues—what we call *socioscientific* issues.

We were interested in knowing how students would respond to socioscientific issues. Would they identify the controversy between competing points of view? Would they initially identify one or more points of view, or would they only identify the different points of view when specifically asked to do so? How would they describe these different points of view? We considered there to be two aspects to a point of view: a position with respect to the controversy and a justification for taking that position. Nearly all students responded with interesting, thoughtful ideas about the issues.

We gathered data in four topic areas:

1) forestry management practices from the points of view of environmentalists, forest company representatives, forestry workers, union representatives, and academics;

"This story is about people debating the issue of clearcutting, logging, and extensive forest damage. Some people think that too many trees have been cut down, whereas others are saying a good enough job is being done with reforestation."

2) the use of animals in research from the points of view of university medical researchers and animal rights activists;

"One view was that animals are needed for medical research to help save human lives. The other view was that it was wrong to dissect animals for medicine because they couldn't stand up for themselves."

3) the safety and aesthetics of tanning from the points of view of dermatologists and suntanning parlour clientele;

"Well first of all I don't suntan and I wouldn't know which is better. But I think the sun would be better than the salon because it is far away and the salon is so close to your body. There must be more ultra violet in the salon because you get darker than the real sun."

4) the economic and health consequences of toxic waste leaking on the grounds of a company which is the economic mainstay of a community from the points of view of town members, and union and company representatives.

"Yes because I wouldn't really care if it just made me sick or something. Besides I wouldn't think that if it was polluted the gov't would allow it to be in our tap water."

These socioscientific issues represent a range of topics, some of which are part of the formal school curriculum, such as forestry, and others which are not, such as toxic waste. Some issues, such as suntanning, are personal in nature in that students have control over whether they suntan or not; other issues, such as forestry, are public issues in which students will have influence through participation in a variety of political processes.

METHODOLOGY

Data were collected from approximately 5600 randomly selected students and classrooms throughout the province:

- 360 students in Grades 7, 9, 10, and 11 participated in a semi-structured, one-on-one interview. These students responded to one issue.
- 5250 students in Grades 7 and 10 completed booklets distributed in class. These students responded to two issues. In the booklets, students responded to the first issue by selecting answers from choices provided. These choices were derived from what other students had said in pilot interviews. For the second issue in the booklet, students responded in their own words.
- Issues were presented to the students in one of two media formats: a short video tape or a one-page article written in two-column, newspaper format.

In the interviews and in the written response sections of the booklets, students described the issue in their own words, identified the different points of view presented, and gave their own point of view. The students were then presented with a second, related story that attempted to make the issue more personally relevant to them. For example, in the animal topic, students were asked if they needed a brain tumour removed whether they would select a group of scientists to operate on them who had trained on monkeys, or a group who had trained on a computer-simulated model of the human brain. The consistency of the students' points of view across these different stories within a topic was noted.

Using both qualitative and quantitative techniques, the research team analyzed student answers and developed a coding scheme to describe the variety of responses. A team of teachers from around the province then used this instrument to code students' booklet responses.

Some overall findings are presented below along with some general differences in responses among topics, between males and females, between Grades 7 and 10, and between print and video formats.

STUDENTS' DESCRIPTIONS OF ISSUES: GRADES 7 AND 10

To explore students' initial response to an issue we asked them to describe what the story was about. The students' answers to this question varied greatly. The wide variety of individual responses to the same presentation indicates that students do not "hear" or "see" the same story.

The following graph illustrates the distribution of responses to the first question, "What is this story about?" The majority of students did not initially describe the story in terms of conflicting points of view as defined in the context of the study.

A few students (10%) initially described *2 or more points of view;* they identified the different positions presented and provided justifications for those differences. Often these students gave concise answers, usually exposing some of the underlying values behind each point of view (e.g. "This is about animal rights vs. human needs").

24% of the students initially described only *one point of view* (e.g. "This is about cruelty to animals"). The mention of cruelty implies a position that it is wrong to use animals because it will hurt them and allows this response to be categorized as a point of view for this study.

25% of the students described the issue in terms of a *sense of topic*, expressing no sense of disagreement on the issue (e.g. "This is about animals"). This category of response can be contrasted with the previous example "This is about cruelty to animals." This response contains no position on the controversy and is, therefore, not considered a point of view.

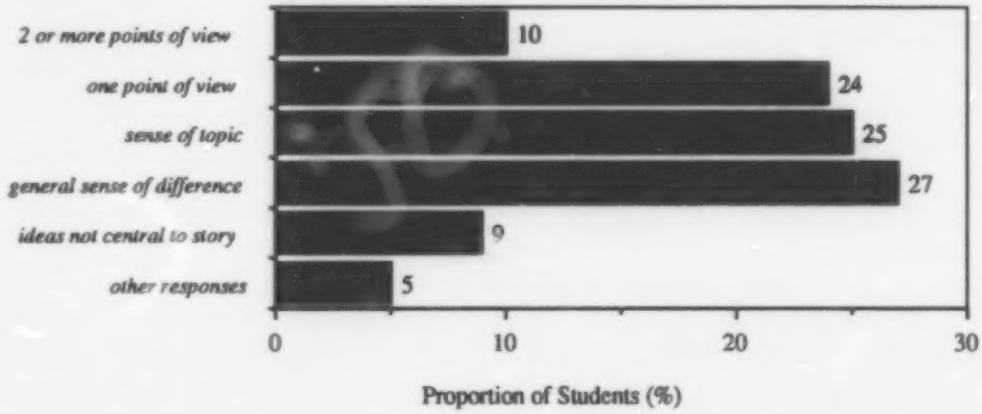
An additional 27% of the students described the issue in terms of a *general sense of difference*, expressing no sense of topic (e.g. "Some are for, some are against").

Another 9% of students initially responded by providing *ideas not central to the story* (e.g. in suntanning "This is about a model").

An additional 5% of students initially gave *other responses*: they didn't know, they didn't care, or they confused the two issues.

Combined Topic Responses to:

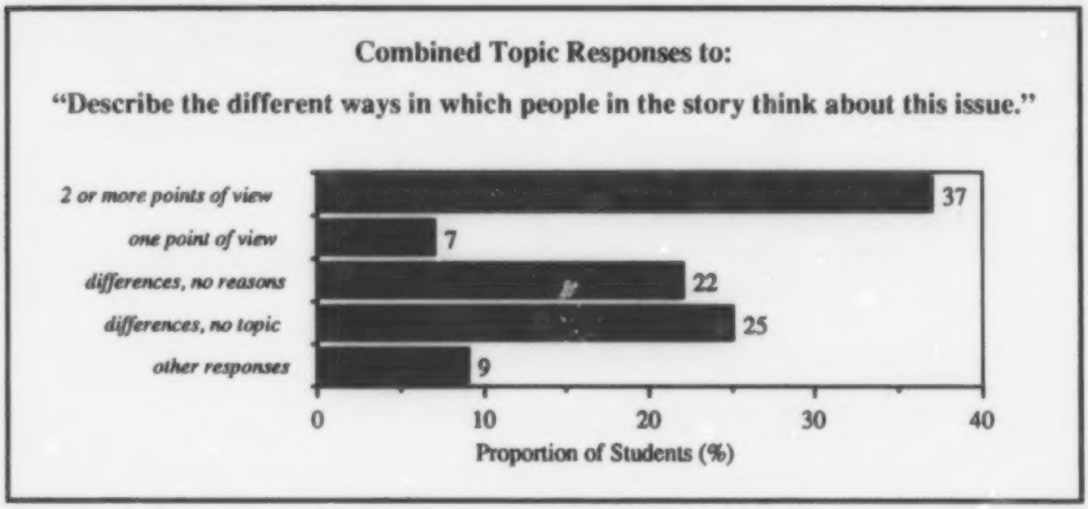
"What is this story about?"



When students were explicitly asked in the second question to identify the different points of view presented, 37% of the students were able to describe 2 *or more points of view*, while 7% of students responded with *one point of view*.

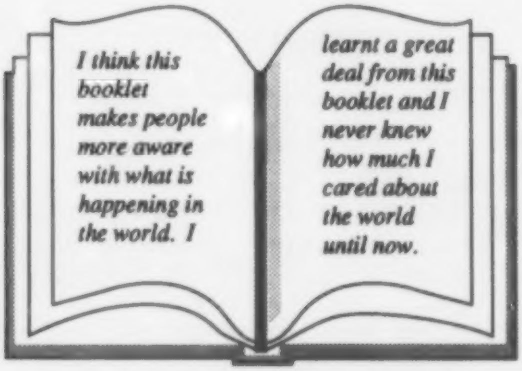
22% of student responses were classified as *differences, no reasons* (e.g. "Some are for, some are against tanning") and 25% of student responses were classified as *differences, no topic* (e.g. "Some are concerned, some aren't").

As in the first question, 5% of the students gave *other responses*: they didn't know, they didn't care, or they confused the two issues.



Combined Topic Responses to:

"Describe the different ways in which people in the story think about this issue."



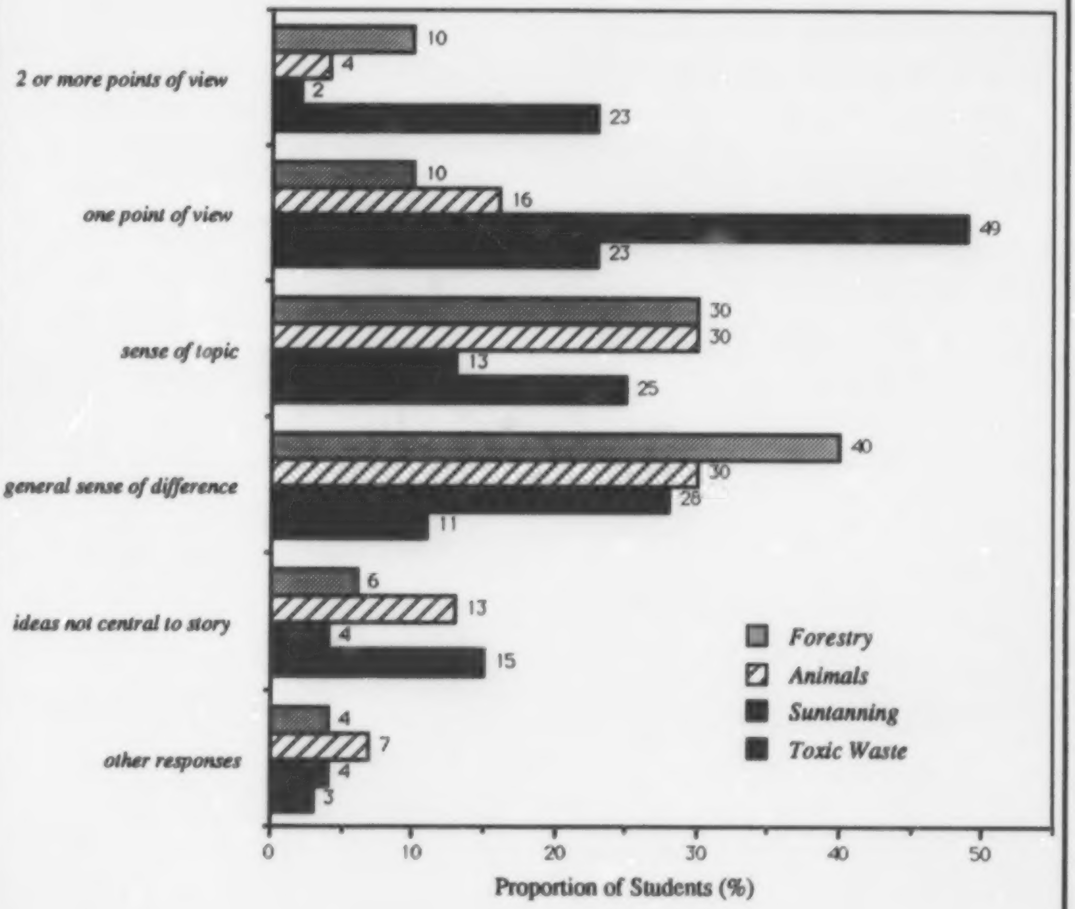
I think this booklet makes people more aware with what is happening in the world. I learnt a great deal from this booklet and I never knew how much I cared about the world until now.

VARIATIONS BY TOPIC

Students were more apt to differentiate points of view in some topics than in others. The highest percentage of students' responses describing *2 or more points of view* for the two questions was evoked by the two environmental topics. Toxic waste was the highest followed by forestry. Few students identified *2 or more points of view* in the use of animals in research, and even fewer students did so for suntanning.

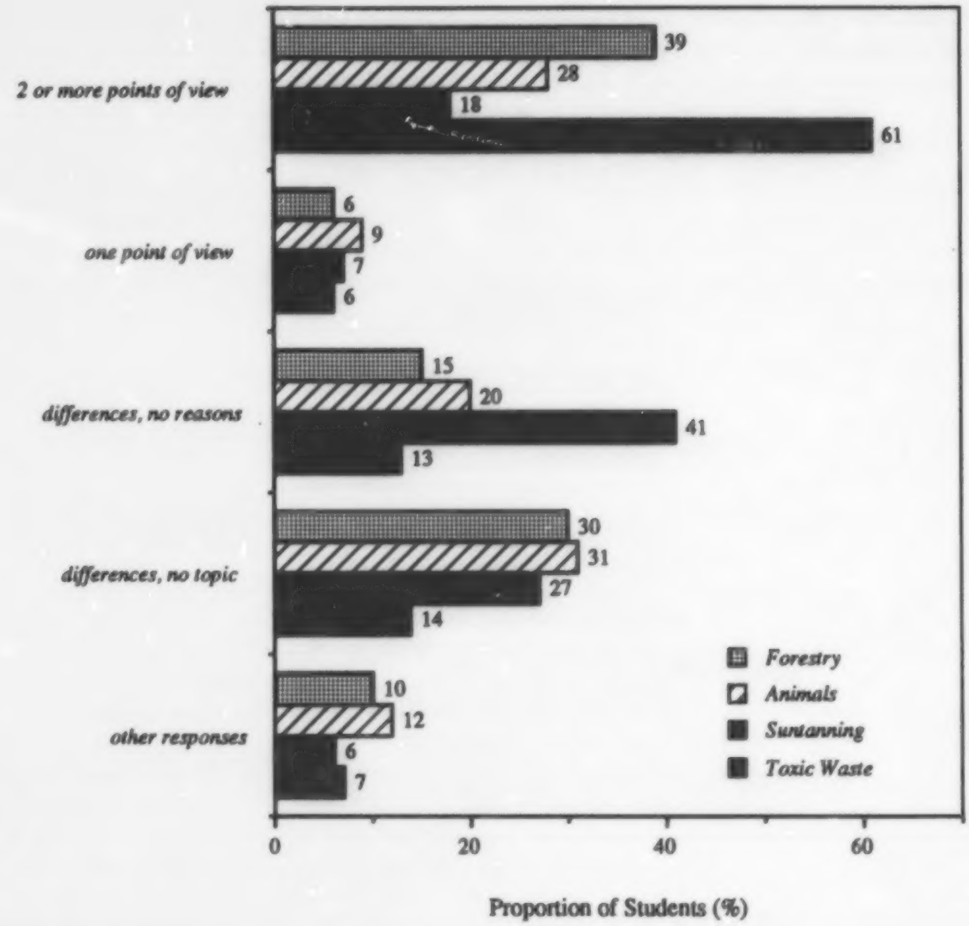
Responses by Topic to:

"What is this story about?"



Responses by Topic to:

"Describe the different ways in which people in the story think about this issue."



What enables students to recognize and describe different points of view remains an open question. Some possible factors are: the students' familiarity with the topic (extensive or little exposure), the format of the presentation (print/video), the perceived status of the people presenting their points of view (lay people/experts), and the nature of the story (drama/news).

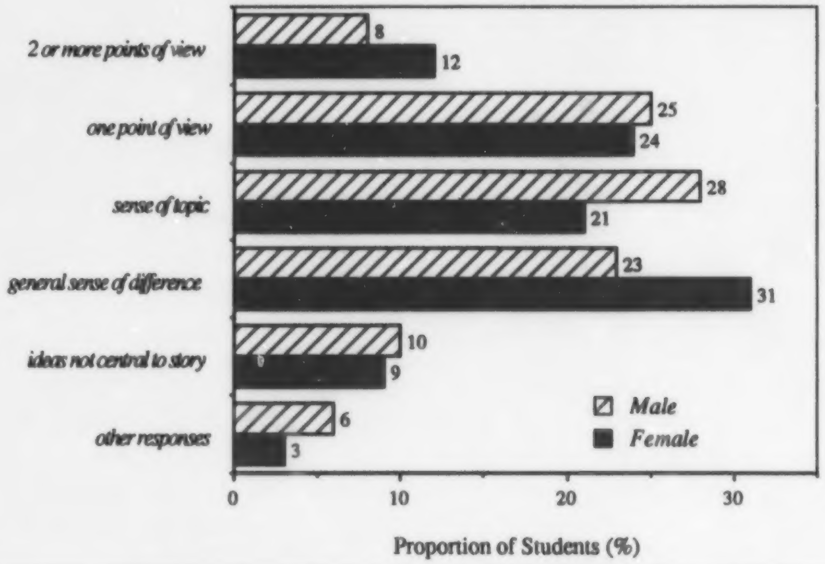
Educators should be aware that students' abilities to discern whether there is a controversy and to describe the nature of that controversy vary greatly and that students' abilities demonstrated in their response to one topic may not necessarily transfer to another topic.

VARIATIONS IN RESPONSES BY GENDER

Across all issues there were some very interesting differences between genders. Females tended to identify the different points of view more often than did males when responding to both questions. Females tended to describe the issue more often in terms of a *general sense of difference* without a sense of topic, whereas males tended to describe the issue more often in terms of a *sense of topic* without a sense of difference.

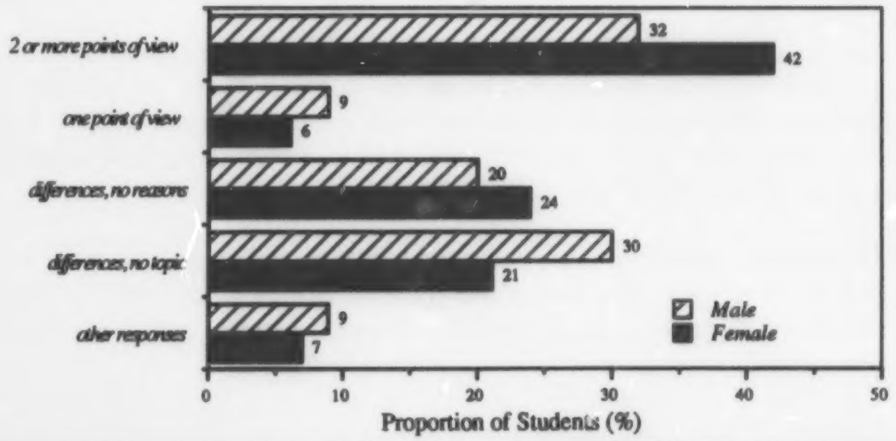
Responses by Gender to:

"What is this story about?"



Responses by Gender to:

"Describe the different ways in which people in the story think about this issue."



VARIATIONS IN RESPONSES BY GRADE

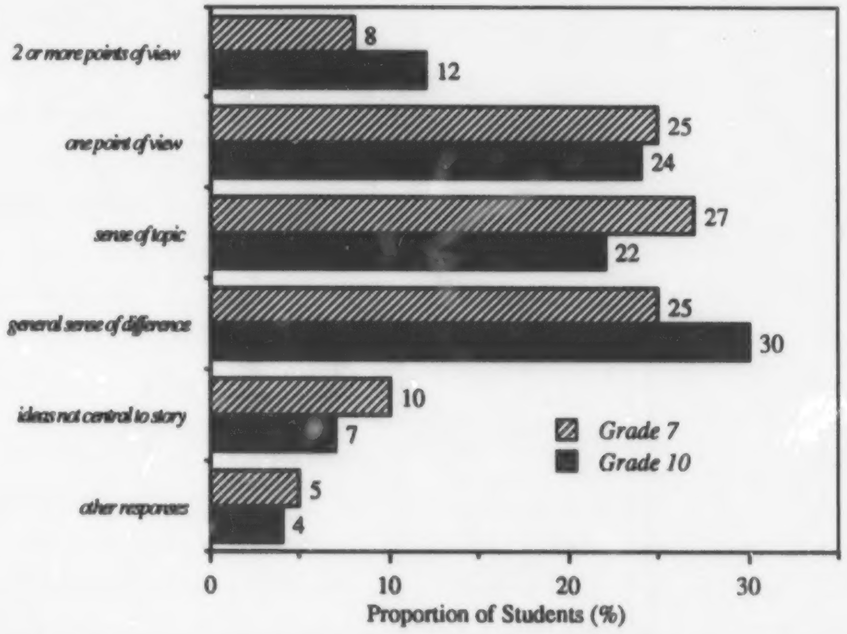
Not surprisingly, for both questions, older students in Grade 10 identified *2 or more points of view* more often than did younger students in Grade 7.

In response to "What is this story about?" students in Grade 7 more than students in Grade 10 described a *sense of topic* without identifying differences while Grade 10 students more than Grade 7 students described a *general sense of difference* without mentioning a topic.

Regardless of grade, there will be some students who need assistance in identifying the conflicting points of view presented in a socioscientific issue. However, there will be more such students in the lower grades.

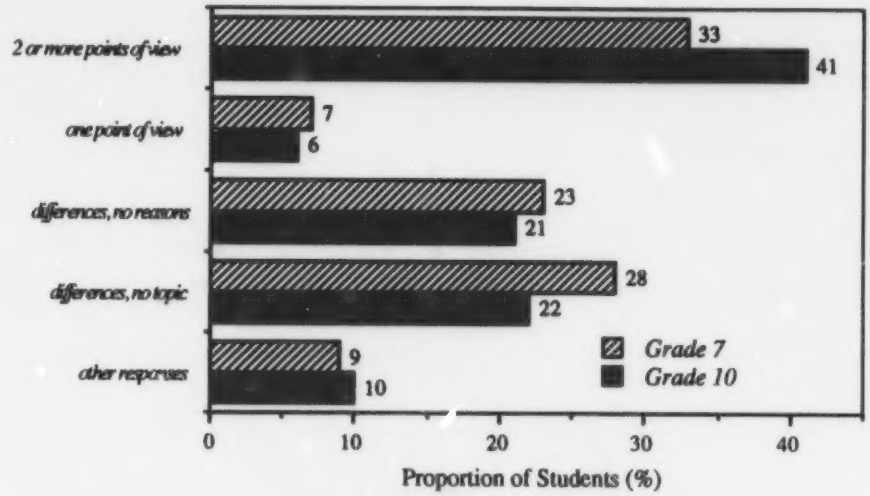
Grade Responses to:

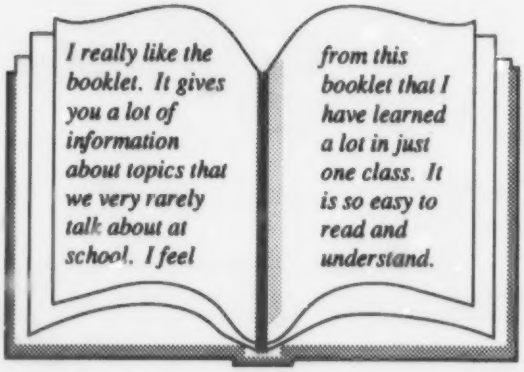
"What is this story about?"



Responses by Grade to:

"Describe the different ways in which people in the story think about this issue."

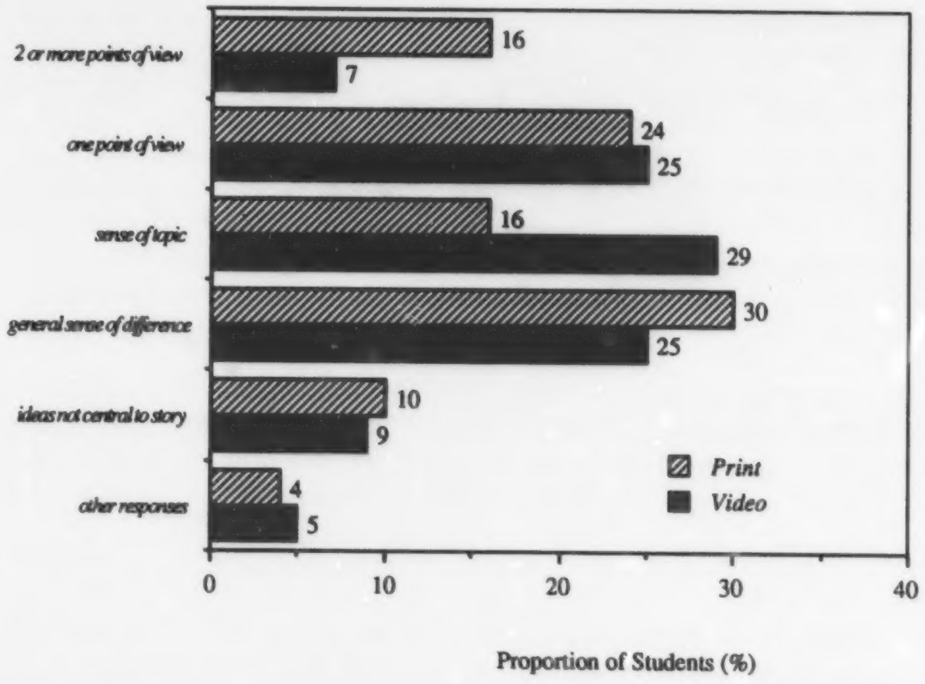




I really like the booklet. It gives you a lot of information about topics that we very rarely talk about at school. I feel from this booklet that I have learned a lot in just one class. It is so easy to read and understand.

VARIATION IN PRESENTATION FORMAT

An interesting difference occurred between presentation formats. In both questions, print more than video encouraged students to identify *2 or more points of view* . In response to the question, "What is this story about?" video more than print encouraged students to describe a *sense of topic* while print more than video encouraged students to describe a *general sense of difference.*



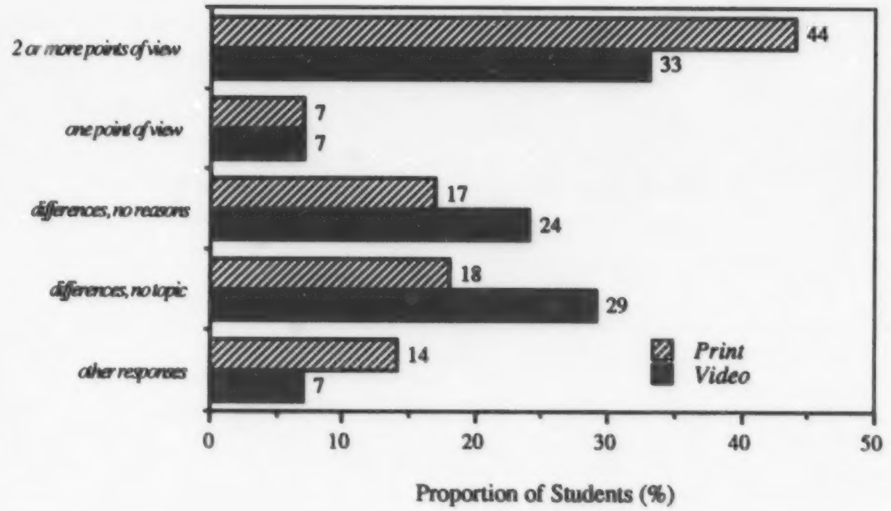
Responses by Presentation Format to:
"What is this story about?"

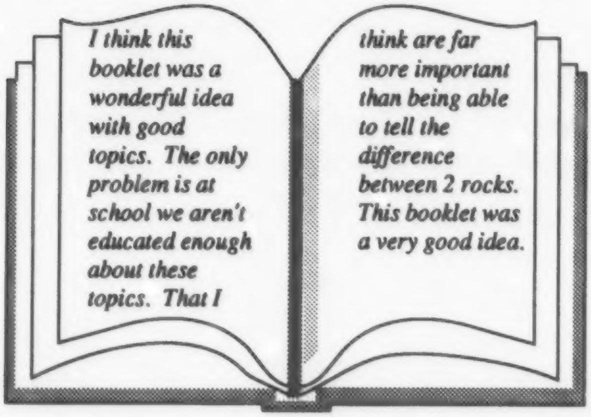
As well, print more than video produced more "I Don't Know/ Don't Care" responses, categorized as *other responses*, particularly in Grade 10 males.

Teachers should consider using a variety of media formats when presenting socioscientific issues to their classes, but they should be aware of the strengths and weaknesses of each presentation format.

Media Responses to:

"Describe the different ways in which people in the story think about this issue."





I think this booklet was a wonderful idea with good topics. The only problem is at school we aren't educated enough about these topics. That I think are far more important than being able to tell the difference between 2 rocks. This booklet was a very good idea.

Students' Own Points of View on Issues Presented by Video or Print

When students were asked to give their points of view on the topics, they did so in a variety of ways. In general, students' views encompassed concerns for conservation and the need for compromise. The most frequent viewpoints in forestry were to cut fewer trees, to use selective harvesting practices, and to replant to preserve wilderness. In the use of animals in research, students favoured the view that animals have rights and should not, therefore, be used in experiments; some would agree with the use of animals in experiments if there were no pain and suffering, and some would use animals only if the experiments could be shown to be important. In the tanning story, there was a strong sense that tanning, particularly in the parlours, is harmful to one's health, and should only be done occasionally. In addition, many students commented that tanning on the beach is not as harmful as tanning in the parlours because the sun's rays are "natural". In toxic waste, where there is a conflict between the economy of the community and the health of its citizens, students favoured the health of the community, but many requested more information.

There were interesting gender differences in students' points of view on these issues. In general, females identified with caring and conserving views toward issues, for example, to preserve wilderness, whereas males favoured more utilitarian viewpoints, for example, to use animals in research for important experiments. In general, Grade 10 students seemed to have more utilitarian views than Grade 7 students, while Grade 7 students seemed to be more conserving.

There were some differences in students' points of view arising from the mode of presentation. For example, in the toxic waste issue, more students who read the print story than those who saw the video would request more information to determine what action to take in regard to the leaking toxic waste.

Students' Own Points of View About a Second, Related Story

Students' points of view in terms of the original story remained relatively consistent when presented with a second, related story that attempted to make the issue more personally relevant to them. In the forestry issue, when students were asked to take sides and vote between a citizens' committee request to restrict logging and a company's prediction that the town would then suffer economically, the students who had originally chosen to preserve wilderness tended to side with the citizens' committee. On the use of animals in research issue, students who had originally expressed a point of view that animals should not be used in research said that, given the situation in which they required a brain tumour removed, they would choose those scientists to operate on them who had practised their techniques on a computer-simulated model of the brain, not those scientists who had tested their technique on monkeys. In the suntanning issue, students who initially saw tanning as being unhealthy said that, if given the opportunity, they would not use the coupon that offered three free sessions in a new modern suntanning salon in their neighbourhood. In the toxic waste issue, students who originally called for the company to conduct a major clean-up of the waste-site said that they would not risk drinking the water from the town if a friend offered it to them.

Other students, when presented with a second situation that called for a more personal decision, either made a decision in contrast to their original position, or they avoided making a choice. It should be noted that consistency in students' points of view is not always to be preferred. Some students developed a deeper understanding of the issue as a result of being challenged by the questions. In these cases their changed position reflected their new ideas.

STUDENTS' INFORMATION SOURCES: GRADES 7 AND 10

Students reported gathering their information from a variety of sources.

There was variation across topics in the importance of school as a source of information as shown in the table below. Forestry was the topic most widely reported as having been studied in school (72%). Comparatively, 57% of students reported having studied something related to toxic waste in school, 37% of students reported having studied something related to the use of animals in research in school, and 25% reported having studied something related to suntanning in school. If they had studied these issues in school, they were most likely to have studied them in science.

Percentages Of Students' Responses To:
"Have you studied anything about this issue at any grade level in school?"*

	FORESTRY	ANIMALS	TANNING	TOXIC
SCIENCE	26	15	15	31
SOCIAL STUDIES	20	4	1	8
CURRENT AFFAIRS	15	7	5	13
OTHER	15	12	7	16
DID NOT STUDY	28	63	75	43

* Percentages may add up to more than 100% because of multiple responses.

Overall, exposure to these topics in school increased with age: students in Grade 10 reported that they had studied these issues in school 5-10% more often than did students in Grade 7. This increase took place primarily in science in all topics except forestry where the increase occurred in social studies.

About 60% of the students reported that outside of school their primary source of information was television, and within that 40% specifically cited television news. Many students, particularly in suntanning, also reported getting information from magazines (18%).

The reliance on television as the main information source outside of school decreases as students grow older. More Grade 7 students reported television news as being their main source of information (43% vs. 38%). More students in Grade 10 than in Grade 7 relied upon magazines, newspapers, and other people for information (29% vs. 20%).

There was an interesting variation in gender and across grades in the predominance of the place of television. More males than females reported learning about these issues from television (59% vs. 51%), whereas more females than males received their information from other sources such as magazines (11% vs. 7%).

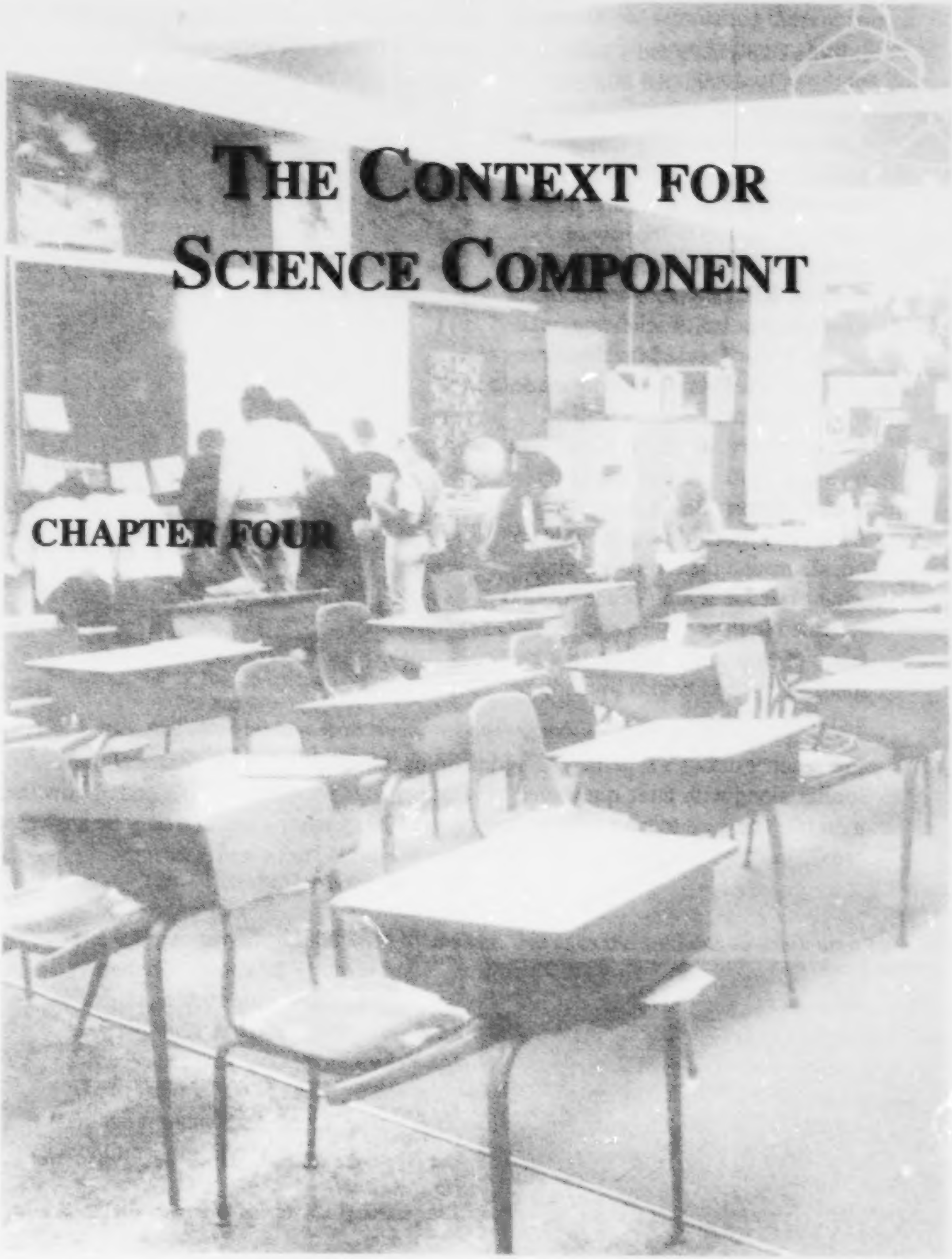
Students bring information from diverse sources to discussions about socioscientific issues. Students need to articulate their initial ideas about these issues in a supportive atmosphere in the science classroom and develop methods to assess and construct defensible arguments.

LOOKING TO THE FUTURE

In today's society, students and adults must make decisions about socioscientific issues. A choice can only be made if different points of view are recognized. Data from this component of the assessment suggest that, over the four topics used, more than half the participating students were not able, when specifically asked, to recognize and describe more than one point of view in an issue.

A greater emphasis needs to be placed on developing students' abilities to:

- recognize and describe different points of view, and
- construct and support their own point of view when presented with issues.



THE CONTEXT FOR SCIENCE COMPONENT

CHAPTER FOUR

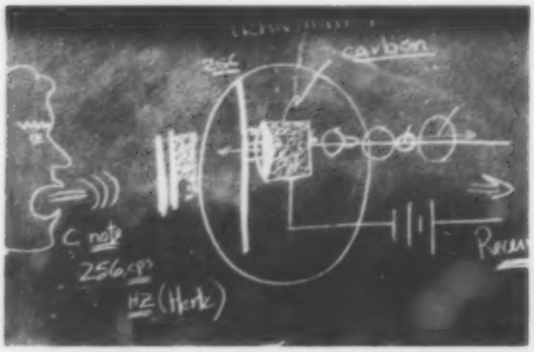
THE MANY FACES OF SCIENCE TEACHING: TWO REALITIES - TWO CLASSES

Class One

It looks like a standard secondary science classroom that might be seen anywhere. With one exception. Looming over the long teacher's bench that parallels the front wall, hovering over the sinks and periodic table, giving life to the row of storage cupboards, hangs a series of posters. These posters depict the men and women of science as well as concepts or periods in the history of science. All of them were made by the students. On one wall, atomic theory, alchemy, phlogiston; on another, likeness of scientists such as Robert Boyle, Humphrey Davy, and Madame Curie. And so on, all around the room. As students enter class the setting of the room is reflected in their smiles and the sense of eagerness they bring with them. The class begins immediately.

WILHELM
ROENTGEN

The teacher draws a schematic diagram on the chalk board of an electrical transformer along with three questions: 1) what is it?; 2) what does it do?; and 3) how does it do it? They are to play a game, a version of 20 questions that can only be answered "yes", "no", or "maybe" by the teacher.



Is it an electrical device?
Yes.
Is it an electromagnet?
Maybe.
Does it produce light?
No, it does not.
Are those coils?
Yes, they are.
Did they have electricity going through them?
Yes they do. All good questions.
(20 minutes later)
Does it change volts into amps?
No, it does not.
Does it change the voltage from one level to another?
Yes, it does.
Does it make the voltage higher and the amperage lower?
Yes, it does.
Excellent. O.K. You know what it is. You know what it does. Now the plot thickens. How does it do it?

There is a clear sense of excitement on the part of the students as they zero in on the answer. But the answer alone is not enough, the teacher does not quit until the students have developed a reasonably good explanation for the operation of the transformer related to changing magnetic field because of the alternating current source. This portion of the class lasts 40 minutes. Following it, some students cluster around the teacher seeking elaboration or confirmation of their own ideas, others break into small groups to discuss applications of transformers. One boy explains his theory to others by flapping his arms to demonstrate the buildup of magnetic field around his body.

CLASS TWO

Except for the occasional poster, chart, or outdated news clipping, the room has a sparse look. No evidence of science can be seen and there is little sign of science equipment. This lesson was the second in a unit on the Human Body. The teacher begins by asking the students to take out their textbooks. As they do so, the teacher asks:

> What's the human body made of? Yes?...
> *Cells and organs.*
> He said cells and organs. Organs are made up of...
> *Tissues.*
> Tissues. And we have organs. What's an organ?... name one. Yes?
> *A part of the body.*
> A part of the body. Okay, give me an example.
> *The kidney.*
> Okay, the kidney is an organ.
> *The heart.*
> And when we have some organs working together and [they] are one department of the function of the body, we have a word...
> *System.*
> System. Okay name me a system of the body. Yes?
> *The respiratory system.*
> What system is that? What does it do? Okay, it has to do with breathing, right? Name me another system of the body.

The teacher moves from answer to answer. He asks the students to think about all the "wonderful things" the human body can do, as a way of introducing a 17-minute video tape about the "body symphony". The video presents many facts about the body—"there are over 20 thousand, billion cells in the body; when you take a step the thigh bone takes 1,000 pounds of pressure"—with little evidence or reasoning that would support the claims. At the end of the video, the teacher immediately hands out an assignment sheet and asks students to work in groups of four to sort items into two columns: one for "similarities," the other for "differences."

> All human beings... how are they similar; how are they different? Give me ten of each.

Students work for four minutes amid much chatter about other things. Their interests appear to lie elsewhere. Soon, the teacher asked how many students had done the reading previously assigned. Only two hands go up (both boys). One boy is asked what the reading is about. "Heart," the boy says. The second boy says, "Skin." "Yes," replied the teacher, and immediately concludes, "Our time is up. Let's get ready for gym."

What do these two contrasting examples tell us about science teaching?

EXPECTATIONS FOR SCIENCE TEACHING

In the introduction, we raised the question of what people value in science teaching. The following considerations for planning student learning in science are guidelines which science educators have developed over the years.

Less emphasis on	More emphasis on
Teaching by telling	Exploring relationships Constructing meaning Developing understanding
Learner as a passive recipient of knowledge	Learner as an active participant in constructing knowledge. Discussion of scientific ideas; writing; questioning; debating.
Extended periods of isolated individual activity	Flexible use of individual, small group, and large group settings.
Rote memorization, without context	Reasoning and investigating to develop understanding.
Focus on "the result" or "right" answer	Processes to obtain results
One acceptable process	A variety of processes

Although the two classes previously described are composites, we see illustrations of these two emphases. In Class 1 the students went beyond receiving information. They were engaged, energized, active; willing participants in a discovery. They were given a problem to work out, they exchanged and built on each others' knowledge, their understanding of the subject was taken into account, and the lengthy exchange gave time to reject as well as to develop ideas.

Class 2 also illustrates certain characteristics of teaching. First, students displayed facts for the teacher. The dialogue suggests that learning science has to do with remembering the appropriate terms, definitions, and examples. Second, students use one-word answers to the teacher's questions that the teacher often repeats. Third, no student-student interaction occurred. In fact, it appeared that students did not even listen to each others' responses. Only the teacher made judgements about the correctness of the answers or extended the dialogue in any way. Only a trace of "higher-order" thinking or "making sense" of the material came in the sorting of similarities and differences among human beings.

DESCRIPTION OF THE STUDY

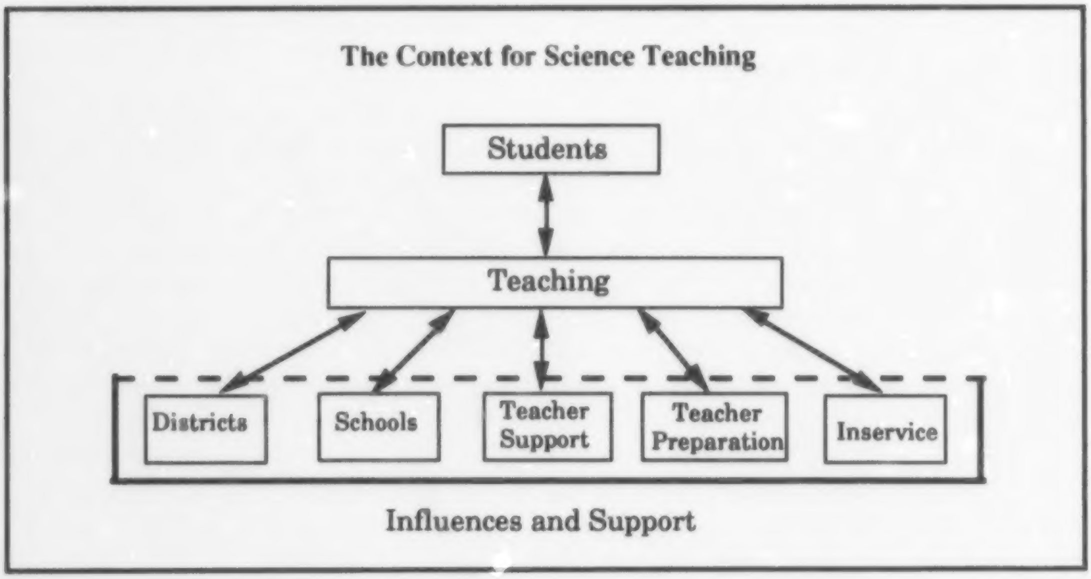
While the other components of this assessment focused on what students had learned or could demonstrate in science, this study examined the context in which that learning took place. In a sample which represented various geographic areas of the province, we visited 10 districts where we observed and interviewed a total of 60 teachers of Grades 3, 4, 7 and 10. We observed most teachers on two occasions, except those in Grade 3 who were seen only once. In addition to recording the classroom activity and keeping extensive notes of what occurred during each classroom visit, observers summarized what had taken place in each five-minute segment of the lesson. This record keeping provided a gauge of the activity across classrooms. From each class we randomly selected four students, engaged them in a science activity and talked to them about their views of science. Researchers also interviewed the teacher, science department head, principal, and school district personnel responsible for curriculum and instruction and/or the professional development of teachers.

The classroom observations, along with the interviews and other supporting data, provided the basis for preparing case studies that were developed for every class. These became the basis for drawing out the findings that follow.

This study is indicative of science teaching in the province. However, the sample was not large enough to be a statistical representation and therefore, results cannot be generalized across all districts, or to any one particular district.

Results of the Study: The Different Parts of a Complex Picture

Our visits to the science classrooms, schools, and districts in British Columbia brought us into contact with a range of activities, practices, and perspectives regarding science teaching. Information was collected in the three general areas: "Influences and Support", "Teaching", and "Students" as shown below. Together these make up the complex picture of science teaching in the province.



Interviews with teachers

From our interviews it was apparent that science held a special place for some teachers who found science to be important to them on a personal level; they tried to recreate that sense of personal involvement for the students. Many teachers talked about the necessity of listening to students when planning for science teaching. Others spoke about the wonderful world of science and what it meant for children to "do" science. In the words of one teacher:

> ...it is one of the most enjoyable and exciting subjects for me in the curriculum because I find the kids really want to do science... Everything that you talk about in the scientific process, if you allow that to occur in the classroom, then it is just a natural thing for them to want to do.

Other teachers saw science as a marginal subject that they taught infrequently or with little confidence. These teachers often expressed concerns about the subject and the lack of support they received for teaching it. While many of them spoke of a lack of materials and inservice, others questioned the way science was regarded by their districts or schools. One teacher put it this way:

> **You just have to take a tour of our school and see some science stuff stuck in this cupboard and some science stuff stuck in that cupboard. What impression does that give you in terms of what value is placed on science? It would be the same if they took all the librarians and said, 'we're not using librarians any more.' If they do that, what...does it say to the kids? What...does it say to the teacher? If it's not important enough to have...those facilities and staff there, then how important is it?**

This concern about the value placed on science was reflected in the comments of many teachers. They felt that science as a subject was not valued at the school or district levels and that other initiatives had taken priority.

THE TEACHING OF SCIENCE

Teachers' perceptions of science as a school subject were often supported by our observations of their teaching practices. We observed teachers in some schools who enthusiastically brought the world of science to their students. These teachers approached the subject with passion and commitment and their classrooms were delightful places. In those classrooms we saw different strategies in use and students who appeared to be engaged intellectually in the subject. The students were "doing science."

However, we also saw many classrooms that did not reflect this kind of science. There we saw lecturing and recitation without much student engagement; when we did see "hands-on" activities in these classrooms, students appeared to be going through the motions rather than being intellectually engaged.

Both the *Year 2000* initiative and the *Science Probe* series encourage teachers to integrate subjects being taught. While the *Year 2000* encourages the integration of science with other subjects such as mathematics, the *Science Probe* series suggests that teachers integrate different areas within science at the junior secondary level. When we asked teachers whether or not they integrated science with mathematics, many reported that they did. However, when we probed for examples, we found that much of this activity took place on a relatively superficial level and consisted mainly of graphing and charting. Similar results were reported for the integration of other subjects such as language arts. However, as in many other situations, exceptions occurred. Some teachers, particularly those at the primary level using a thematic approach, integrated many aspects of their program. Others at the secondary level, however, did not agree with the concept of integration at all and saw "their" subject as being a completely distinct one.

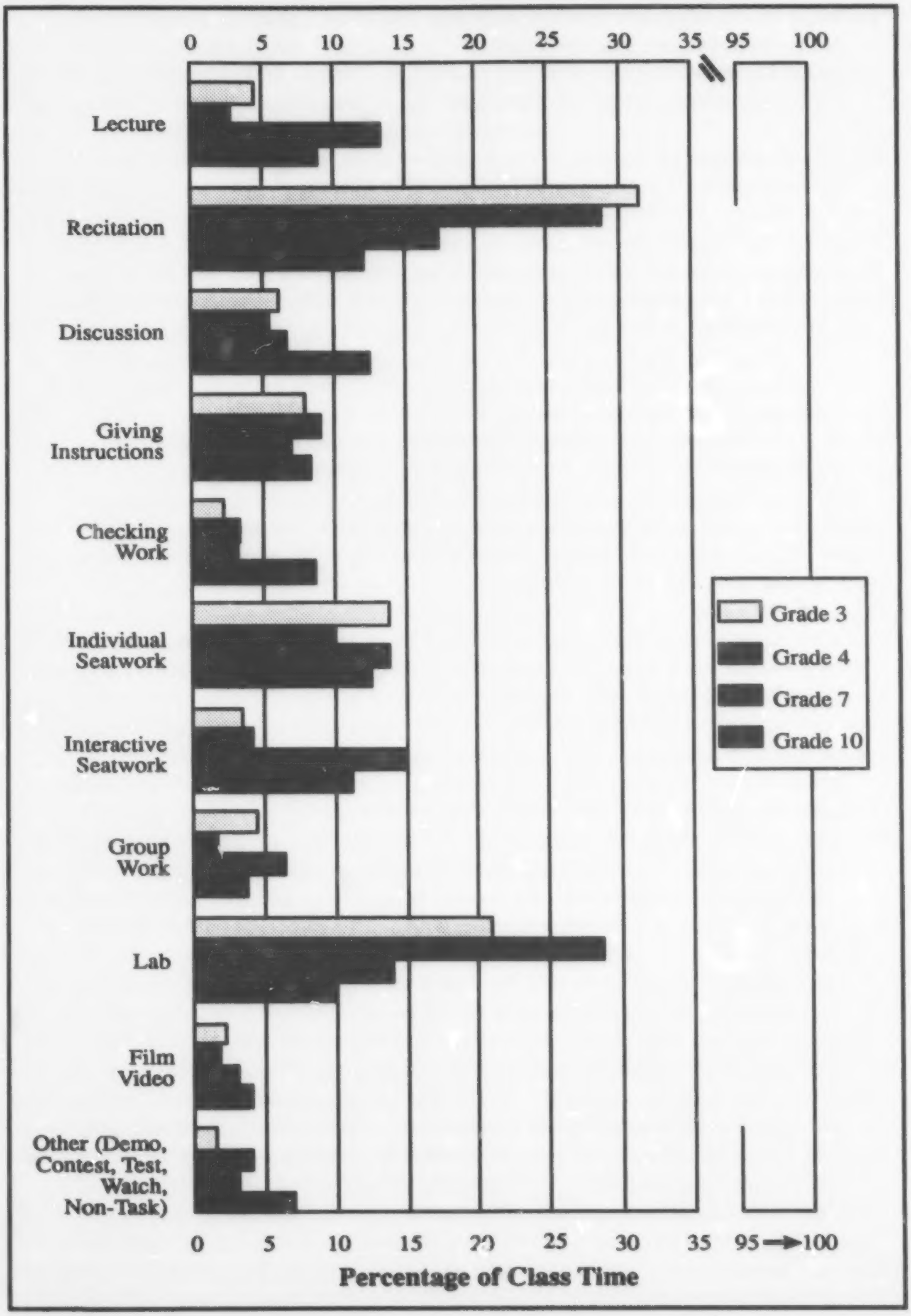
PERCENTAGE OF CLASS TIME

There was a wide range of activities observed across all the 60 classrooms visited. These activities are listed on the vertical axis of the following graph which is titled, "Percentage of Class Time."

Recitation, which occurs when a teacher presents material but stops occasionally to have students answer questions or repeat answers, occurred more often than any other activity. While recitation decreased from Grade 3 to Grade 9, lecturing, which includes straight teacher talk, tended to increase.

Three kinds of seatwork were coded: individual seatwork where students worked by themselves, interactive seatwork where students consulted with each other, and group work which involved co-operative learning (in which each student has a particular task in the group). Across the grades, individual and interactive seatwork together took between 15% and 30% of the instructional time. Group work, which involved at least some elements of co-operative learning, occurred infrequently.

Laboratory work varied from "hands-on" activity in the elementary grades where children handled materials to more formal labs in Grade 10 where students worked from a text or manual to undertake an experiment. As Figure 2 shows, laboratory work decreased from Grade 4 to Grade 7 to Grade 10. It should be noted, however, that these observations do not speak to the quality of that laboratory activity.


0
5
10
15
20
25
30
35
95
100
Lecture
Recitation
Discussion
Giving Instructions
Checking Work
Individual Seatwork
Interactive Seatwork
Group Work
Lab
Film Video
Other (Demo, Contest, Test, Watch, Non-Task)
Grade 3
Grade 4
Grade 7
Grade 10
95 ⟶ 100
Percentage of Class Time

THE BROADER CONTEXT OF SCIENCE TEACHING

Classroom teaching is central to the context in which students learn science, and there are many influences on that teaching.

Factors that might be labelled "what goes on in the mind of the teacher" include:

- the teacher's own academic background in science;
- his or her philosophical position about the nature of science and what it means for children to "do" science in the classroom;
- the approaches used to teach certain topics; and
- the teacher's general attitude toward science as a discipline and its importance in the school curriculum.

Other factors influencing the teaching of science pertain to the situations in which teachers do their work. These include:

- the availability of teaching materials and equipment;
- teachers' collegiality with staff members and contact with other science teachers;
- the "tone" of the school and the administrative practices of the principal;
- the policies and practices of the school district in professional development; and
- the availability of resource people such as helping teachers or curriculum consultants in science.

All these factors affect the broad context of science teaching. Many of them will have to change if science is to move from being a marginal to a mainstream subject. The following sections discuss some of the factors more fully.

TEACHER BACKGROUND, PREPARATION, AND PROFESSIONAL DEVELOPMENT

We view learning to teach as an ongoing process spanning undergraduate coursework, teacher pre-service, and in-service activity. Teachers told us many different stories about their teacher preparation in science. For some it had been a strong engaging experience. One teacher, for instance, described the combination of undergraduate science courses together with a methods course on how to teach science as having provided the basis for current work in the classroom that this teacher described as "process science." As we saw the teaching we could see evidence of that understanding. For people such as these, teacher education had been important in determining the way they viewed science and the way they taught. Very often those who subscribed to this view could cite a pivotal course or professional development experience in science education that had had a major impact on them. We also identified other cases where teachers, despite their limited science background, who had sought out information and in-service, and had reflected on the nature of science and what it means for children to "do" science, seemed to bring that understanding and enthusiasm to their classrooms. However, they proved to be in the minority of those in our sample.

Other teachers, however, very often those who reported having little science background, weak teacher preparation, and virtually no in-service education in science, found themselves feeling inadequate and often overwhelmed at the prospect of teaching it. Typically, it was these teachers who said that science was not a priority in their classrooms. One Grade 7 teacher who had no academic background in science, and no preparation for teaching it, told us that until word came about our visit the teaching of science had been avoided for some time.

DISTRICT AND SCHOOL ETHOS

We looked for linkages of various kinds such as those between teaching and support, and science teaching and other subjects. These linkages do not represent statements of cause and effect. Rather, they represent relationships between the different aspects of the complex context in which science teaching occurs. They appeared quite consistent across the districts and schools we visited. We now turn to these.

Although none of the 10 districts we visited saw science as a main priority at the time of our study, some districts appeared to be providing much more support to maintain science teaching than were others. We saw evidence that such support made a difference in the way science was being taught in classrooms. We found that where districts placed an emphasis on science, generally in the form of a science coordinator, part-time or full-time, elementary teachers were more likely to teach science. However, even in the districts that had made a strong effort in the past to support science, such support now appeared to be in decline. In our interviews rarely could teachers identify any specific science in-service offered during the past three years. Where teachers reported having deliberately sought out in-service activity, however, such activity appeared to have made a difference. One teacher, reported not taking any science in-service since the textbook series, STEM, had been introduced several years ago. Direction or assistance coming from the district was only in the form of materials. The district once supplied a resource person who took students for field trips. Although the services of this person had been well used by the schools, the position had been eliminated. The teacher felt very concerned about this situation and missed the support that once was available. Many teachers we spoke with shared this concern.

School support also varied. Where science was found to be a priority in the school we generally found a committed principal, one or two teachers with a particular interest in science, and teachers working together to improve the delivery of the subject. One energetic, interested, dedicated "science" person on staff served as a catalyst for the rest. This help was enormously appreciated and appeared to encourage teachers to try something new and take a more innovative approach to teaching. Where more than one of these elements was missing, we generally found that science had been, as so many described it, "put on the back burner."

Teachers and principals talked frequently about the impact of the *Year 2000* which was seen both positively and negatively in terms of how it supported science teaching. For some it had opened the door to the possibilities of a fresh approach to teaching. They saw the principles of the *Year 2000* being transferable to science teaching. For example, one Grade 7 teacher told us that the ideas generated by the *Year 2000* led to a new program for science teaching in which that teacher also became the learner in the classroom. This class, conducted entirely by students, proved to be a rewarding experience for the observer and apparently for the class as well. On the negative side, many others, particularly at the intermediate and secondary level, reported that the *Year 2000* initiative had taken priority away from subjects such as science.

SCIENCE AND LANGUAGE TEACHING

Our assessment also included 16 classrooms where science instruction occurred in French. From an analysis of the interviews, particularly with the teachers of the French Immersion program, the similarity between successful science teaching and successful language teaching became evident in certain classrooms. Where the observer saw what appeared to be sensitivity to language instruction (i.e., allowing students to use language among themselves as a way of learning) the science instruction was satisfactory or better. Where we saw language used mainly as a tool to reflect the 'right answer' (typical of recitation teaching) we also saw what appeared to be less than satisfactory approach to science teaching.

One is tempted from this to argue that teaching is teaching; the subject does not matter. In drawing this particular linkage we did not have that in mind. Rather, the teachers we observed who had success in both science and language arts seemed to have a deep understanding in both. The teaching went beyond technique to a way of understanding and a way of dealing with science so others came to understand it.

STUDENTS

We randomly selected four students from each classroom, presented them with an investigation activity in science as an 'icebreaker' and then interviewed them about science. We found that many students had ideas about future careers by Grade 6, and in some cases as early as Grade 4. While the choice of career often seemed independent of their experience in science, students' desire to take science courses in secondary school appeared linked to their experience in the elementary grades.

The most impressive thing to come out of the interviews with students had to do with their views about what constituted good science teaching. We did not talk about their present science teacher for ethical reasons; rather, we asked them about science teaching in general. They spoke to us about the kind of science activity they enjoyed. What impressed the research team was how their views paralleled what the literature in science education calls "good" science teaching. For the more thoughtful of them, hands-on activity alone was not sufficient. They were most interested and enthusiastic about science when they experienced "hands-on" activities that were linked to "minds-on" understanding.

HANDS-ON, MINDS-ON SCIENCE

The literature in science education sometimes suggests that "hands-on" activity in science provides an end in itself. Our observations in classrooms and interviews with students pointed to an interesting linkage between activity in science and intellectual engagement. In many cases we saw students simply going through the motions doing what was asked of them. In other situations we saw an engagement of the mind, something we refer to as "minds-on". Our analysis of the data led us to offer four different classroom situations.

Minds-on — Hands-on
Minds-on — Hands-off
Minds-off — Hands-on
Minds-off — Hands-off

"Hands-on" activity did not necessarily involve the minds of the students. While they did respond better to this activity than they did to "chalk and talk", it was when they became intellectually engaged that science took on meaning for them. When that point was reached, almost any topic appeared to interest students. Those who talk about "hands-on" science are thus only half correct. Activity for activity's sake is not adequate. We must strive for an engagement of the mind as well as of the hands. We found that the finest examples of teaching engaged children in what we called "minds-on" science. Such teachers alternated "hands-on" and "hands-off" activities in order to facilitate this engagement.

LOOKING TO THE FUTURE

This study produced a picture of uneven science teaching in the schools of British Columbia. Although few in number, we did observed classrooms at every grade that reflected many of the ideals of science teaching found in the literature. The teachers appeared to be thriving despite a system that provided very little encouragement or support for science. In the majority of classrooms observed in elementary schools, science appears to have become a marginally important subject in a curriculum that has seen other subjects emphasized. In secondary classrooms we frequently saw lecturing and recitation without much student engagement; when "hands-on" activities were in evidence in these classrooms students appeared to be going through the motions rather than being intellectually engaged.

These observations come at a time when the importance of science in society is being increasingly emphasized, not only for the general education of our young people, but for the international competitiveness of our nation. It is noteworthy to discover that support for science appears to be dropping in the districts observed.

To rectify this situation, we encourage a renewed commitment to science education throughout the grades. Such a commitment must come at all levels. The Ministry as well as the districts must do whatever is necessary to give science a higher profile. A simple starting point would be to signal that science be taught as a subject at all grades in the elementary school. One initiative that would send a serious signal to the educational community would be to undertake a program to encourage "science champions" who promote the cause of science teaching at the district, school, and group level. Encouragement, training, and support will be required.

A new generation of teachers has now entered the schools. They see change in classroom practice in new ways. For them, the sharing of ideas with other teachers and the testing and retesting of those ideas in the classroom will count more than any top-down imposition of practices to be followed. Support strategies, along with a new vision of science teaching and its implementation, must reflect the intents and aspirations of such teachers.

Clearly, increased commitment and support will provide the beginning for a renewed mission for science education in the province. However, part of that renewal must also deal with the re-examination of how, and for what purpose, we teach science in the schools. If good teaching follows from deep understanding, then improved teaching follows from improving one's understanding of the subject and how to teach it. Single workshops and quick fixes will simply not do. Teachers must have the support to grow in their understanding of science and science teaching over time. The challenge in the years ahead will be to enable teachers to reflect on their notions about science and science teaching and then help bring that vision to their classrooms.

COMMON ISSUES

CHAPTER FIVE

The various components of the assessment have, in several instances, collected data about the same issues in very different ways. The following section attempts to explore some of the common findings from the four components. Evidence for the conclusions discussed under the following common issues comes from the classical, performance, socioscientific issues, and classroom context components.

GENDER ISSUES

The concern for gender equity has many manifestations, both in terms of classroom practices and in terms of career choice. For example, studies throughout the world have shown that females are very under-represented in most science and mathematics related occupations. In this report we have described selected aspects of student performance in the components that have yielded gender differences. These differences were apparent despite the attention that was paid in this assessment to the use of the most unbiased items, tasks, and materials available.

While the source and the significance of these differences have long been the subject of numerous conjectures, it is first and foremost of importance to examine the extent and nature of these differences for the purpose of attempting to redress any inequities that exist in this area. We are encouraged by the data that indicate that there were very few gender differences in performance by females and males on the items and tasks used in all components of this science assessment. Even in those topic areas such as electricity or earth sciences, where previous assessments have shown gender differences of 20 to 30 percentage points in favour of males, the difference is significantly less than previously measured. One particular finding from the performance component is noteworthy in this regard. One station at each grade level involved the manipulation or construction of an electrical circuit—the type of item that often generates large gender differences on paper and pencil questions. Our results showed there were virtually no differences observed between the males' and the females' performance at all three grade levels.

A second finding of general interest is that on items or tasks involving an environmental topic or theme the females generally took a more conserving view of the environment than did the males and the differences tend to get larger as students get older. This was true in both the attitudinal data and in the knowledge of environmental issues as assessed in the classical, performance, and socioscientific issues components.

Positive shifts from previous assessments were also noted in the area of the gender ratio of secondary science teachers. In previous assessments this ratio has remained fairly constant at 90% males to 10% females. In this assessment the data from the teacher questionnaire indicated that the ratio for Grade 10 teachers had changed to 80% male to 20% female.

We view these indicators as positive signs that the concerns expressed in previous assessments about gender inequity may be gradually being addressed. In spite of these promising trends, it remains important to continue to challenge any perceptions that science is primarily a male subject.

CRITICAL THINKING ISSUES

Students and adults face an increasing number of complex, and sometimes controversial issues in which they must identify differing points of view, recognize underlying assumptions, and evaluate evidence which often comes from competing experts. Schools play an important part in helping students deal with such issues by providing knowledge and information from competing perspectives. However, the interaction of school knowledge and everyday life is not simple and science educators are increasingly recognizing that critical thinking and decision making must also be an explicit part of the science curriculum.

The essence of the various definitions of critical thinking in the B. C. science curriculum guides for each level can be captured by the succinct statement found in the elementary guide: "Critical thinking is the ability to identify central issues, to recognize underlying assumptions, and to evaluate evidence. The student should be able to recognize stereotypes and biases, to identify essential, verifiable, and adequate data, and to draw conclusions." (p. 9) Each of the components of this science assessment contributed information with respect to the assessment of critical thinking.

The evidence from the classical component suggests that, by and large, B. C. students at all levels are able to recognize scientific patterns of deduction and induction: that is, students are able to say whether or not, and to what degree, a conclusion follows from a set of data and propositions. In addition, the data from the performance component indicate that when students are given a specific question to investigate, they are able to develop, use, and defend strategies for answering the question and for dealing with conflicting data from experiments they devise and carry out.

While students are quite good at evaluating evidence, they have less success at identifying central issues and recognizing underlying assumptions. For example, the open-ended question in the classical component asking students to identify central issues in a descriptive paragraph was not well answered. In the socioscientific component, where students were presented with an untitled story containing two or more conflicting points of view and asked to identify the central issues in the story, few students framed the story in terms of a controversy. Even when specifically asked, less than half the students were able to identify more than one point of view with its underlying assumption. However, results showed that students' ability to do this depended on their knowledge of the topic. This suggests that critical thinking may be tied to content knowledge. While students may learn the importance of asking questions about assumptions, biases, stereotyping, etc., their ability to construct answers to these questions depends on their familiarity with the topic. This is backed up by evidence from the socioscientific component that suggests students are more able to think critically about issues they have studied in school. However, data from the Context of Science component of this assessment suggest that, at best, only limited time is devoted to the critical analysis of issues.

ENVIRONMENTAL AND SOCIOSCIENTIFIC ISSUES

Environmental and socioscientific issues have become one of the major concerns of society today. All facets of the media such as newspapers, radio broadcasts, and television news and current affairs programs continuously expose us to environmental and socioscientific controversies. There are those who maintain that the future of the human race, and even of the earth, is dependent on solving present environmental problems. As such, environmental and socioscientific issues must be seen as an important area in the science program.

The majority of the students at all grades can be termed to have positive attitudes toward environmental issues in general, and almost none of the students at any grade had what might be termed as an "unfriendly" environmental attitude. With regard to the economic use of natural resources such as the forests or fish, a majority of students hold attitudes and beliefs that might best be termed "conservationist"; they are greatly concerned about the preservation of resources. They are generally skeptical about issues such as beneficial claims made by drug companies, and express concern about the problems created by the overuse of chemical fertilizers and the production of atmospheric contaminants. These attitudes are changing significantly over time; students are becoming more and more environmentally conscious and they are also becoming more critical with regard to associated socioscientific issues. However, students report that they do not commonly study socioscientific topics in school; they receive much of their information from outside sources.

At the present time, students are not generally proficient at recognizing and describing more than one point of view or "side" to an issue. When dealing with environmental and socioscientific issues, few "right" answers exist, and students must be provided opportunities to exercise critical thinking skills; they must be able to identify central issues, recognize underlying assumptions, and critically evaluate evidence. They must be able to recognize stereotypes and biases; identify essential, verifiable, and adequate data; and draw meaningful, well-thought-out conclusions. If the positive attitudes that students have are to be translated into beneficial action, environmental and socioscientific issues must be presented, discussed, and analyzed as part of the British Columbia science program.

TEACHING PRACTICES ISSUES

Teaching practices remain central to what children learn and the attitudes they develop about their future participation in science. Most educators contend that for good science teaching to occur, a variety of instructional strategies should be used and students should be intellectually engaged in the activities taking place in their classrooms.

On questionnaires, teachers reported using a wide variety of strategies in the teaching of science. Observations of classroom practice and in-depth interviews with teachers confirmed that some teachers did bring variety to their teaching. In these classrooms, hands-on activity, group work, and presentations, all leading to interesting class discussions, were observed. However, this practice was not evident in the majority of the 60 classrooms observed. The variety in teaching approaches appeared to fall within a somewhat restricted range of activity. For example, observations included very little evidence of co-operative learning and inquiry teaching, approaches to instruction that many educators feel to be of major importance. The data also suggested little student use of library materials, computers, or field trips to augment the science program. The data from observations suggest that the range of activity may well narrow for students as they move up the grades. A steady decrease in laboratory/hands-on activity from Grade 4 to Grade 10 was observed.

Those who argue for active learning contend that students should take part in determining what they learn and how they learn it. In the classrooms observed, some evidence of teachers listening to their students as they planned the curriculum was seen, but not as much as might have been expected given the current emphasis on the *Year 2000*. Instruction still tended to be teacher directed with little student-to-student interaction, regardless of the strategy in use. One item on which students clearly gave their opinions involved the "hands-on" approach to science teaching. From the literature one might assume that "hands-on" science provides an end in itself. According to the more mature students interviewed, this was not the case. While they value "hands-on" activity more than "chalk-and-talk" and worksheets, they also see the value of being intellectually engaged in the subject. The key ingredient to good science teaching appeared to involve engagement of the mind.

This summary of teaching practices points up a mixed picture of science teaching in the province. To place the sole responsibility for this at the door of the teachers would be unfair in the extreme. Teachers receive very little encouragement to teach science, let alone in an interesting and exemplary way.

The successful delivery of any subject at the classroom level must receive support in a variety of ways. Science is no exception. Schools, districts, ministry, and the institutes of higher education all must play a part in creating a positive ethos for science teaching and backing that up in a variety of ways. At this time many groups, nationally and internationally, are calling for more science in schools, and different agencies such as the Science Council, Science World B. C., and the Association for the Promotion and Advancement of Science Education (APASE) are being funded to increase awareness of science in the schools and among the general public.

The results of questionnaires and interviews show that science teaching receives little support currently, to the point that science has become a marginal subject in the curriculum. Teachers, particularly in Grades 4 and 7, reported not having adequate equipment to properly teach science. Where children were observed doing "hands-on" activities, the activities were often undertaken on window ledges around the room to escape sloping desks or because no other space was available. In terms of professional development, very few of the teachers interviewed reported having had any in-service in science within the last five years. In addition, the support that comes from having someone at the district level who acts as a helping teacher has virtually disappeared over the last decade. Teachers miss that support.

Although the general trend in the districts assessed appears to be moving away from an emphasis on the teaching of science, counter-examples do exist. Some schools have made a concerted effort to build science teaching into their planning. In those schools, encouraging results were seen. Central to such planning were science advocates, groups of teachers working together, and principals providing support.

CURRICULUM ISSUES

Science, particularly at the elementary grades, occupies a position of importance far behind subjects such as mathematics and language arts. In giving attention to mathematics and language arts, as some districts have over the last five years, science typically suffers. It became very clear from interviews with teachers, principals, and school district officials that the current *Year 2000* emphasis has tended to move science off the list of priorities of districts where the Context of Science was assessed.

It is not the wish here to argue against the merits of the *Year 2000* or any other curriculum initiative. Rather, two points should be made. First, in general, the *Year 2000* has been interpreted primarily as a language arts initiative, a situation that is disconcerting. The perceptions about this must be changed so that science and other subjects do not suffer as teachers proceed to implement the *Year 2000* recommendations. Second, districts must make stronger efforts to "maintain" levels of support for subjects such as science. This was seen in only one district among the 10 included in the sample for the Context Component of this assessment. Although the curriculum emphasis of this district lay elsewhere, science was being maintained through a resource centre and a part-time district person.

SUMMARY
AND
RECOMMENDATION

All empirical studies and assessments done in British Columbia since 1967, until this assessment, have shown a steady improvement and increase in student performance. The resources that the people of British Columbia have put into education have borne fruit in the area of science.

SCIENCE EDUCATION IS GENERALLY SATISFACTORY

The interpretation of the results of this assessment has shown that science education in British Columbia is generally satisfactory at this time. However, this assessment has also shown that problems are emerging with the teaching and learning of science which, if ignored, could lead to a decrease in the level of satisfaction with science education from what it has been in British Columbia.

These following problems must be addressed:

- a slight, but significant decrease over the last five years in student performance in science, most noticeably at the Grade 4 level;
- a perceived weakness in the development of rational thinking skills in science;
- a concern about students' abilities to recognize and describe different points of view in socioscientific issues;
- a concern regarding the number of students with positive attitudes toward a career in science;
- a concern about the amount of class time devoted to science, particularly at the lower grades;
- a lack of science coordination at the school and district levels;
- a general lack of emphasis and support for science teaching from the district level;
- a pattern, in many classrooms, of science teaching which does not engage learners; and
- a need for professional development in science.

SCIENCE MUST NOT GET LOST

Science must not get lost! In addressing these problems, it is essential to consider that British Columbia is now undergoing a change in education resulting from the recent Royal Commission. The changes are, at present, most noticeable in Primary education and will become increasingly evident at other levels as implementation progresses. During this implementation, schools and teachers are striving to understand these changes and do what is best for students. In terms of science education, the philosophy embodied in the *Year 2000* and subsequent documents, such as the concept of the active learner, integration of subject matter, cooperative learning strategies, reading and writing in science, and the like, have long been an integral part of the underpinnings of science education and are displayed in the methods and the report of this assessment. It is recognized that these approaches and methods are extremely important and beneficial, and educators at all levels of the system must be keenly aware of exactly how and where science fits within the overall structure in each of the Primary, Intermediate, and Graduation Programs.

There are growing concerns over Canada's global competitiveness and the part scientific literacy plays. There is a need for a scientifically literate population which must be more and more knowledgeable about and concerned with environmental and other socioscientific issues of the world. The important part that science must play in the future of the nation and this province, along with the current educational initiatives underway in the province, provides a solid opportunity to develop a program to reform and upgrade science education in the schools of British Columbia.

The Contract Teams, therefore, have the following two major recommendations to make based on the results of this assessment.

It is recommended that schools and school districts should immediately investigate the degree to which science is being taught, and should take measures to ensure that the development of scientific knowledge processes and skills are included in an appropriate amount of instructional time for students at all levels, with particular attention to the Primary Program.

It is also recommended that the Ministry of Education and Ministry Responsible for Multiculturalism and Human Rights should immediately form a task force of interested stakeholders to make comprehensive recommendations for a program to reform and upgrade science education in the schools of British Columbia. The report of the task force should include recommendations for appropriate preservice,and continuing professional development of teachers, and should also include recommendations for development of sound educational curricula, methods, and procedures compatible with the proposed reforms of the Year 2000.

APPENDIX

MEMBERS OF COMMITTEES AND PANELS FOR THE ASSESSMENT

THE ASSESSMENT REVIEW COMMITTEE

This group is usually made up of teachers from various grades, administrators, university/college instructors, personnel from various branches of the Ministry, school trustees, parents, and members of the public representing as many of the geographic zones as possible in the province. The Committee met several times during the assessment to provide advice, guidance, and assistance to the Contract Teams and the Ministry on all aspects of the assessment. Each member of the Assessment Review Committee provided these services for the Classical Component and also one of the other components. For the other components, additional members were recruited who had particular expertise in the research methodology employed. The numbers refer to the school districts in which people work.

Assessment Review Committee

Kerrylou Arndt	22	Vernon
David Bateson		University of British Columbia
Sylvie Beillard	24	Kamloops
Amy Brydon		Ministry of Education
Pierce Farragher		University of Victoria
Johane Fortin	36	Surrey
Jim Gaskill		Ministry of Education
Doreen Grant	70	Alberni
Vaughan Lewis		Ministry of Education
Wendy Lim	38	Richmond
Susan Martin	36	Surrey
Brian Masse	57	Prince George
Donna MacDuff		British Columbia Institute of Technology
Freda O'Sullivan	62	Sooke
Véronique Pourbaix-Kent	61	Greater Victoria
Clay Rutherford	72	Campbell River
Spencer Simmons	47	Powell River
Bill Toth (Chair)		Ministry of Education
Roland Lee Venables	68	Nanaimo
Jim Whittaker	65	Cowichan
Tim Wolthers	50	Queen Charlotte
Dave Yarmish	57	Prince George

Performance Component Review Group

Doreen Grant	70	Alberni
Donna MacDuff		British Columbia Institute of Technology
Rita Platt	36	Surrey
Dave Urquhardt	45	West Vancouver
Jim Whittaker	65	Cowichan
Craig Worthing	38	Richmond

Socioscientific Issues Component Review Group

Kerrylou Arndt	22	Vernon
Susan Martin	36	Surrey
Louise Parker	46	Sunshine Coast
Clay Rutherford	72	Campbell River
Sandy Stewart	3	Kimberley
William Vliegenthart	28	Quesnel
Dave Yarmish	57	Prince George

Context Component Review Group

Wilma Grant	31	Merritt
Tina Manders	85	Vancouver Island North
Brian Masse	57	Prince George
Freda O'Sullivan	62	Sooke
Spencer Simmons	47	Powell River
Charles Stewart	21	Armstrong-Spallumcheen
Tim Wolthers	50	Queen Charlotte

Item Review Committees

Item Review Committees for the Primary, Intermediate, and Secondary levels of the assessment were made up almost entirely of teachers at those levels. Their task was to review and provide advice on every question which might be asked of students. They evaluated each of the proposed items in terms of content, wording, and reading difficulty.

Classical Item Review Committees

Kerrylou Arndt	22	Vernon
Robert Burnside	47	Powell River
Eileen Butts	69	Qualicum
David Cater	88	Terrace
Neale Clark	24	Kamloops
Mark Cresswell	39	Vancouver
Pierce Farragher		University of Victoria
Johane Fortin	36	Surrey
Fred Gietz	1	Fernie
Wilma Grant	11	Trail
Bonnie Halvorson	4	Windermere
Kenneth Konkin	36	Surrey
Maureen Krohman	11	Trail
Donna MacDuff		British Columbia Institute of Technology
Peter Macek	49	Central Coast
Christina Manders	85	Vancouver Island North
Susan Martin	36	Surrey
Brian Masse	57	Prince George
Ian McArthur	24	Kamloops
Laurie Mitchell	69	Qualicum

Louise Parker	46	Sunshine Coast
Amin Saad	43	Coquitlam
Norman Sather	9	Castlegar
Charles Stewart	21	Armstrong-Spallumcheen
Sandy Stewart	3	Kimberley
Don Van Kleek	46	Sunshine Coast
Willem Vliegenthart	28	Quesnel
Jim Whittaker	65	Cowichan
Anthony Williams	43	Coquitlam
Michael Wilson	61	Greater Victoria

French Translation Review Committee

Sylvie Beillard	24	Kamloops
Elaine Day		Simon Fraser University
Catherine Eberlé	39	Vancouver
Johane Fortin	36	Surrey
Gloria Gietz	61	Greater Victoria
Lyse Guay	44	North Vancouver
Sylvain Leclerc	24	Kamloops
Vaughan Lewis (Chair)		Ministry of Education
Véronique Pourbaix-Kent	61	Greater Victoria
André Ruel	71	Courtenay
Amin Saad	43	Coquitlam

Coding Teams

Teachers at each of the program levels were responsible for scoring and coding the students' responses to all the open-ended and performance tasks in the assessment. In addition they made judgements about their satisfaction with student results in these areas. With the exception of the Classical Component, the Coding Teams also acted as Interpretation Panels for the component.

Classical Component Level 1 Open-Ended Coding Team

Jacqueline Campbell	39	Vancouver
Glenn Carter	1	Fernie
Ross Cassie	39	Vancouver
Shelley Davidson	37	Delta
Max Geisthardt	65	Cowichan
Doreen Grant (Chair)	70	Alberni
Laura Kneale	38	Richmond
Wendy Lynwood	61	Greater Victoria
Lori-Ann Peloso	41	Burnaby
Kim Rennie	56	Nechako
Dennis Richards	39	Vancouver
Gerald Soon	36	Surrey
Carla Taylor	40	New Westminster
Anne Wiles	44	North Vancouver
Douglas Wilson	39	Vancouver

Classical Component Level 2 Open-Ended Coding Team

Gerry Anderson	15	Penticton
Laurie Atkinson	22	Vernon
Stephen Cairns	43	Coquitlam
Judy Devereaux	36	Surrey
Susan Diewert	39	Vancouver
Katalin Duval	44	North Vancouver
Bill Gorkoff	9	Castlegar
Maxwell Inkster	43	Coquitlam
Jack Kinakin (Chair)	9	Castlegar
Art Macneil	11	Trail
Janet Madhok	56	Nechako
Armida McDougall	43	Coquitlam
Nevenka Salapura	72	Campbell River
Sonya Sopow	41	Burnaby
Nadine Williams	57	Prince George
Tracy Wright	42	Maple Ridge

Classical Component Level 3 Open-Ended Coding Team

James Alexander	61	Greater Victoria
Dave Allan	42	Maple Ridge
Diana Geller	86	Creston-Kaslo
Joseph Gill	43	Coquitlam
Steve Cardwell	37	Delta
Sandy Ho	43	Coquitlam
Brian Masse (Chair)	57	Prince George
Megan Moore	61	Greater Victoria
Charles Neumann	29	Lillooet
Donna Paproski	44	North Vancouver
Eileen Peltier	65	Cowichan
Shelagh Pryke	69	Qualicum
John Renton	89	Shuswap
Anne Sheridan	61	Greater Victoria
Anthony Soo	41	Burnaby
Joan Wheeler	54	Bulkley Valley

Socioscientific Issues Coding Team

David Danylyshyn	87	Stikine
Joan Eichenlaub	65	Cowichan
Trevor Fowler	34	Abbotsford
Frances Friend	41	Burnaby
William Garby	44	North Vancouver
Patricia Hansen	36	Surrey
Nancy Illman	39	Vancouver
Carol Ireson	2	Cranbrook
Ian Johnson	3	Kimberley
Vaughan Lewis (Chair)		Ministry of Education
John Liivam	30	South Cariboo
Donna MacDuff (Chair)		British Columbia Institute of Technology
Charles McNicholl	39	Vancouver
Christina Manders	85	Vancouver Island North
Susan Martin (Chair)	36	Surrey

Darren Mathison	38	Richmond
Kenneth Morton	88	Terrace
Bickey Nadasen	61	Greater Victoria
Martha Nguyen	52	Prince Rupert
Gail Paniec	1	Fernie
Alberto Rodrigez		University of British Columbia
Mark Schiller	30	South Cariboo
Ed Stanton	39	Vancouver
Michael Taylor	35	Langley
Brian Waring	49	Central Coast
Jim Whittaker (Chair)	65	Cowichan
Anthony Williams	43	Coquitlam
Susan Yao	37	Delta
Carol Zrymiak	39	Vancouver

Performance Component Field & Coding Team

Kerrylou Arndt	22	Vernon
Tom Ayres	36	Surrey
Kim Bondi	42	Maple Ridge
Randy Brogden	28	Quesnel
Amy Brydon (Chair)		Ministry of Education
Val Charison	23	Central Okanagan
Paul Cloutier	88	Terrace
Bill Crerar	65	Cowichan
David Eberwein	41	Burnaby
Paul Fletcher	48	Howe Sound
Helen Forsyth	88	Terrace
Lori Giacometti	27	Cariboo-Chilcotin
Bruce Grady	42	Maple Ridge
Shirley Graham	33	Chilliwack
Ron Graves	27	Cariboo-Chilcotin
Ron Hall	41	Burnaby
George Heyd	65	Cowichan
Fraser Kerley	62	Sooke
Sandra Kraft	36	Surrey
Rick Krawetz	62	Sooke
Perry Lofstrom	28	Quesnel
Colleen Lougheed	62	Sooke
Michael MacDonald	24	Kamloops
Al Mouner	62	Sooke
Al Olson	57	Prince George
Dave Olynyk	7	Nelson
Paul Orlowski	48	Howe Sound
Barb Pawson	23	Central Okanagan
Gordon Player	11	Trail
Alistair Robertson		University of British Columbia
David Rolston	24	Kamloops
Theresa Saunders	57	Prince George
Mary-Anne Smirle	23	Central Okanagan
Tim Spencer	7	Nelson
Mary Lou Stacey	22	Vernon
Elaine A. Sturgeon	15	Penticton
Maurice Toporowski	11	Trail
Ken Williams	42	Maple Ridge
Marianne Wood	33	Chilliwack

Interpretation Panels

These panels, one at each program level, were made up of teachers from various grades, administrators, university/college instructors, school trustees, parents, and members of the general public representing as many of the geographic zones as possible in the province. They examined the student results and made judgements about their satisfaction with those results. They identified strengths and weaknesses in students' performance and made recommendations to the Contract Team.

Classical Component Level 1 Provincial Interpretation Panel

Sylvie Beillard	24	Kamloops
Marilyn Bueckert	75	Mission
Diane Corris	22	Vernon
Harold Derksen	42	Maple Ridge
Amato Fantillo	65	Cowichan
Lyse Guay	45	West Vancouver
Dennis Hamaguchi	22	Vernon
Joseph Hillier	68	Nanaimo
Daniel Hudy	2	Cranbrook
Vaughan Lewis		Ministry of Education
Freda O'Sullivan (Chair)	62	Sooke
Susan Richardson	24	Kamloops
Lynn Swanson	35	Langley
Evelyn Voykin	9	Castlegar

Classical Component Level 2 Provincial Interpretation Panel

Marie-France Bérubé	37	Delta
Elisabeth Brinson	64	Gulf Islands
Amy Brydon		Ministry of Education
Raymond Cardin	57	Prince George
Neil Caves	89	Shuswap
Allisen Lambert	64	Gulf Islands
James Murray	24	Kamloops
Spencer Simmons (Chair)	47	Powell River
Connie Simpson	61	Greater Victoria
Sandy Stewart	2	Cranbrook
Keith Thompson	56	Nechako
Lorraine Walsh	36	Surrey
Dean Watson	27	Cariboo-Chilcotin
Brian Wile	61	Greater Victoria
Tim Wolthers	50	Queen Charlotte Islands

Classical Component Level 3 Provincial Interpretation Panel

Raji Biln	39	Vancouver
Sonja Buchanan	35	Langley
Alton Crane	70	Alberni
Ian Dalgleish	80	Kitimat
Jim Gaskill		Ministry of Education
Ruth Johnson	57	Prince George
Jacqueline Lennie	46	Sunshine Coast
Mark Mahovlich	63	Saanich
Timothy McClure	31	Merritt
Ross Norrington		Ministry of Education
Clay Rutherford (Chair)	72	Campbell River
Charles Schilling	1	Fernie
Gordon Schulz	42	Maple Ridge
Bill Toth		Ministry of Education
Michael Wilson	61	Greater Victoria

French Immersion Interpretation Panel

Sylvie Beillard	24	Kamloops
Marie-France Bérubé	37	Delta
Amy Brydon		Ministry of Education
Raymond Cardin	57	Prince George
Catherine Eberlé (Chair)	39	Vancouver
Lyse Guay	44	North Vancouver
Vaughan Lewis		Ministry of Education
Véronique Pourbaix-Kent	61	Greater Victoria
Connie Simpson	61	Greater Victoria